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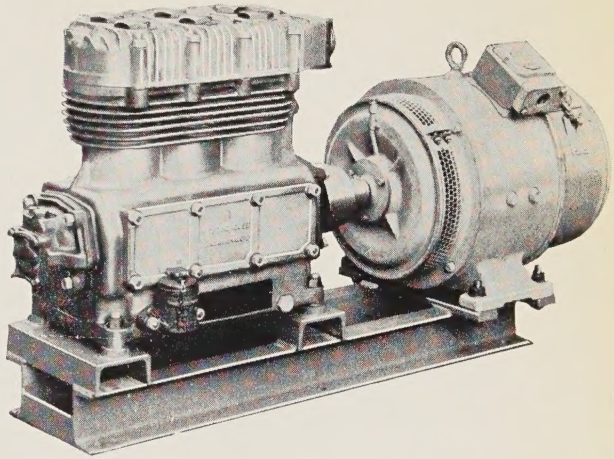
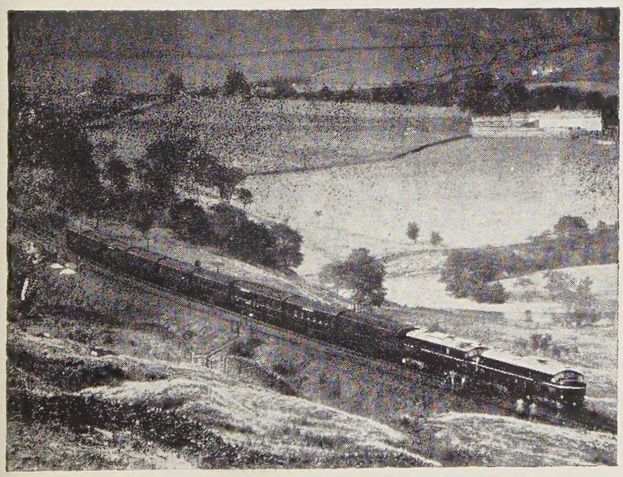


By automatically balancing the vacuum on both sides of the pistons, the tendency for oil to be drawn past the pistons and discharged through the exhaust is practically eliminated. The consumption of oil is thereby greatly reduced, and, as oil fumes are also eliminated, the exhauster can be mounted in a driving compartment. The balance of vacuum is achieved by the airtight crankcase, the crankshaft bearing at the driving end being automatically sealed by an oil-hydraulic pressure seal. This has the additional advantage of making the interior of the exhauster dust and grit proof, an important point when operating in dusty or desert locations.



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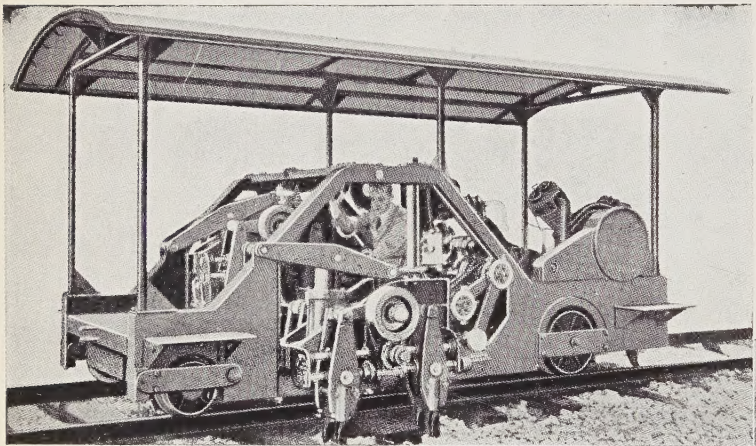

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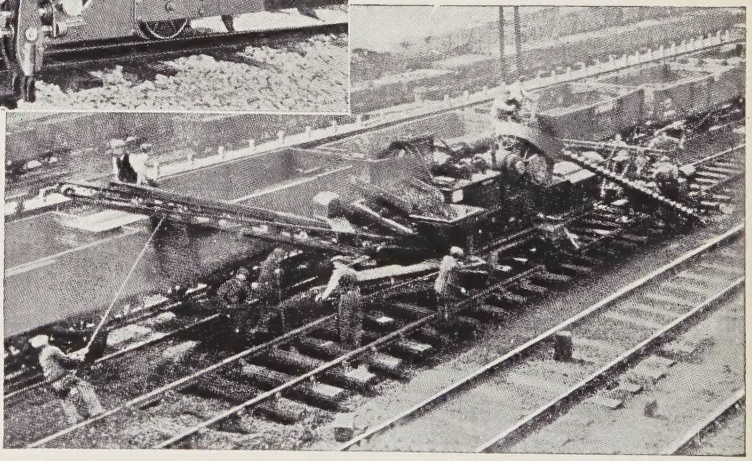

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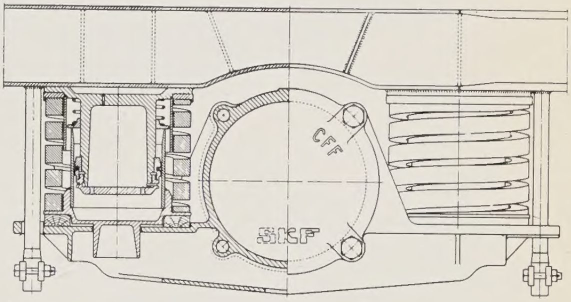

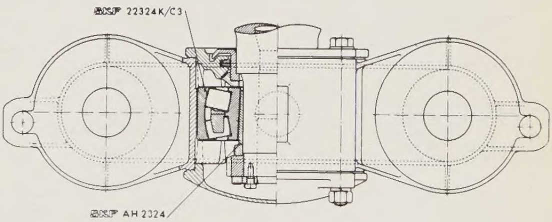

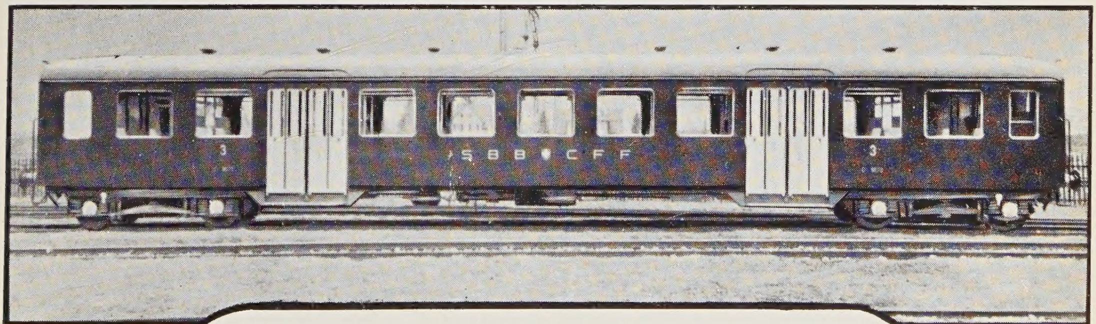

SKF have sold more than 400,000 complete roller-bearing axleboxes to the railways of more than 60 different countries.

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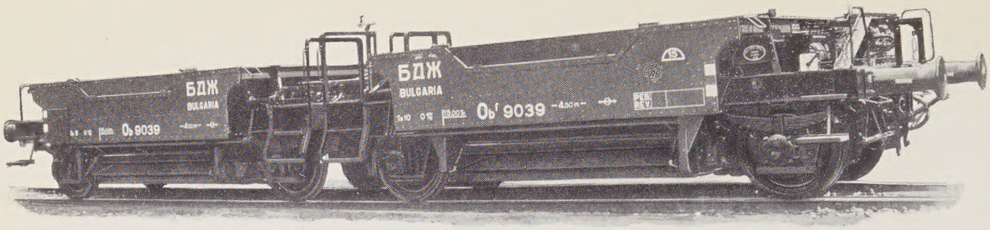

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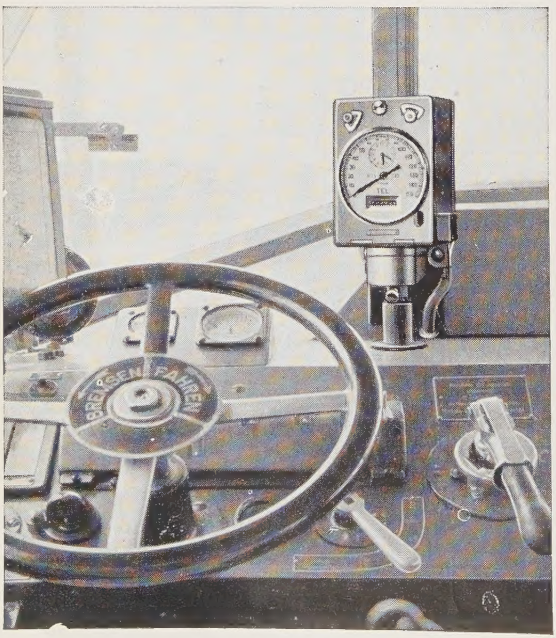

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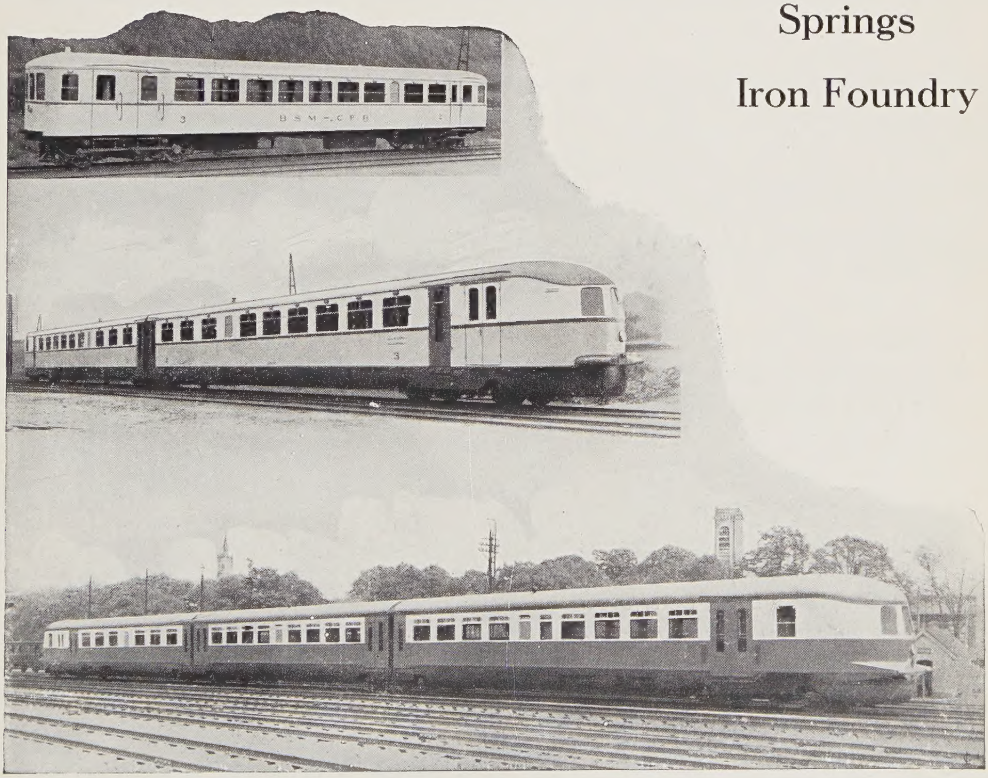
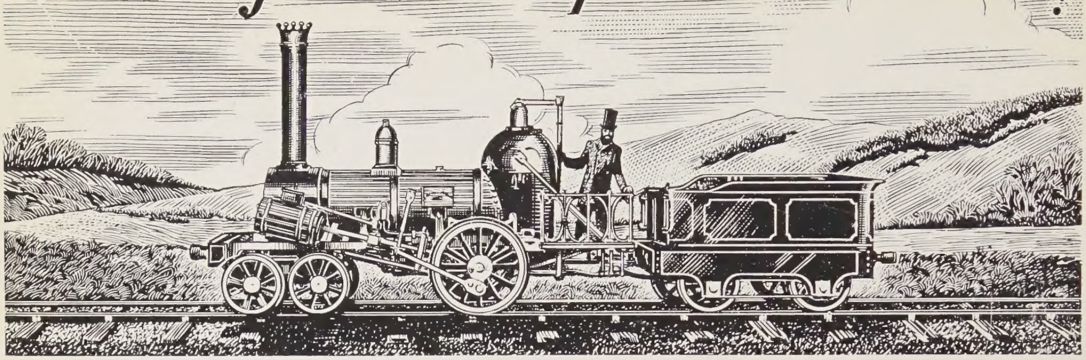


in the days before Superheated Steam!



It is left to conjecture what might have happened if the modern steam superheater could have been fitted to locomotives of the early 1800's.

In modern locomotive design there is no doubt—the superheater is indispensable—in fact the British Railways' "Mallard" No. 60022, holding the world's speed record. is fitted with a

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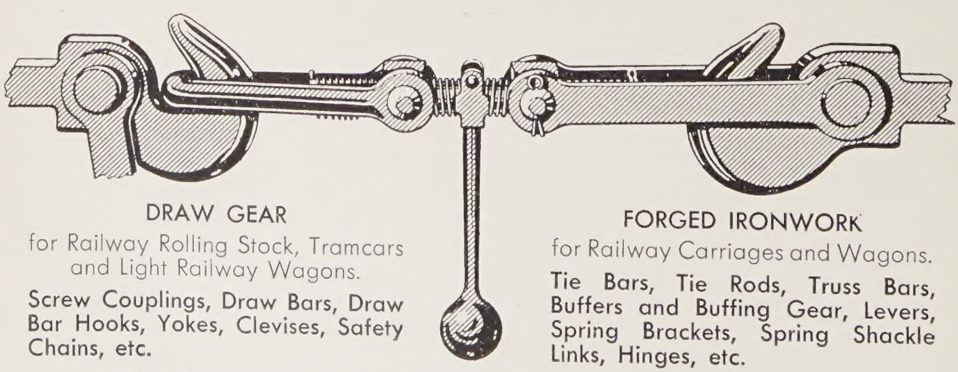

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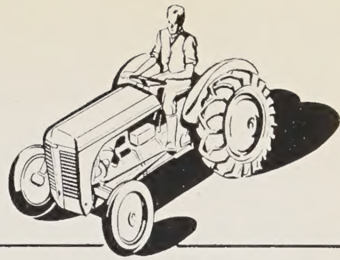
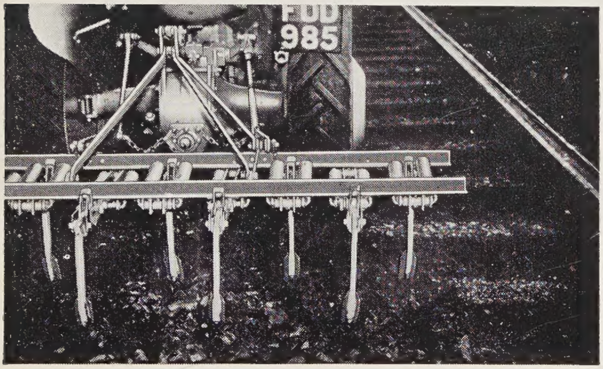


does 24 men's work on British Railways



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An edition in French is also published.

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BULLETIN

OF THE

INTERNATIONAL RAILWAY CONGRESS

ASSOCIATION

(ENGLISH EDITION)

[625 .2 (01]

Research on the kinetic and dynamic properties of a (« dicone ») truck axle moving in a straight line on two parallel rails and on the effect of the angle of cone of the tyre treads on the transverse dynamic stability of railway vehicles,

by ROYER,

Ingénieur en chef des Services de Traction, Société ALSTHOM.

The conicity of the tyres combined with the angle of inclination of the rail tread was introduced in order to cause each axle to move transversely on the track so as to regain its mean position after being displaced transversely therefrom for any reason.

This arrangement always makes for stability if the nosing motion thus produced shows a strong damping characteristic.

In effect, these nosing oscillations which acquire an harmonic character determined by the longitudinal displacement, are on the contrary not damped hence the amplification factor increases with the longitudinal speed over a wide range of the latter.

Thus the nosing motion is specially harmful at the usual high speeds.

Considering that every railway vehicle is made up of more or less complex combinations of masses and springs, each elementary movement which it is able to exhibit in accordance with and about three orthogonal axes of reference, possesses several natural fundamental frequencies.

Under these conditions the nosing motion impressed by the conical design of the tyres, may at certain speeds, behave like forced oscillations and produce a pseudo-resonance effect having a natural frequency proper to the vehicle under consideration, in such cases the transverse dynamic instability may become a menace.

We know from experience:

1) that the use of cylindrical tyres rolling on inclined treads causes the disappearance of this type of swaying motion, but that these tyres may soon assume the conical shape on account of wear due to the inclination of the treads and to traffic followed by other vehicles;

2) that in spite of the unequal wear of conical tyres in regular service, the effect of coning the tyres is maintained and may even be aggravated by wear.

way, always results in a pseudo-slip g that is less than 1/1000.

When a wheel transmits to the rail, in the zone of impact a frictional force in any direction or sense, the movement of this wheel is always accompanied by a pseudo-slip in the same sense as the force.

B. Conditions of equilibrium in torsion of a « dicone » with enforced displacement along a straight line without pivoting whilst rolling on two circles of constant but unequal radii.

An axle having tyres with a conicity $= i$ behaves with respect to the track in the same way as a dicone having an angle of $2i$ at its apex.

We shall allow on the one hand, that the axle under consideration will be displaced at a constant longitudinal speed V on rails having a negligible thickness and that on the other hand, the difference in the rolling circles might be compensated for in normal running by pseudo-slips so slight that $\varphi = Kg$.

Moreover we will assume that at the origin of the movement, say when $x = 0$, the angle of torsion of the axle would be zero.

Let R_1 and R_2 be the radii of the rolling circles with $R_1 > R_2$; g_1 and g_2 being the corresponding pseudo-slips.

At every instant there is a point on the axis of the axle which is displaced by a quantity $dx = Ro\, d\alpha = V\, d\, t$.

$d\alpha$ represents the angle of rotation of the axle and Ro represents the apparent mean radius of the two rolling circles during this interval of time and space, the axle twists through a total angle of $2d\theta$.

By definition in the limit when normal working is attained, namely when the angle of torsion of the axle $2\ \theta$ is constant we have :

$$g'_1 = \frac{R_1 - Ro_m}{Ro_m} \text{ and } g'_2 = \frac{Ro_m - R_2}{Ro_m}$$

with $g'_1\ R_1 = g'_2\ R_2$, since the torque couples applied to the wheels must be equal.

We shall write

$R_1 = R\ [1 + q]$ and $R_2 = R\ [1 - q]$

whence

$$q = \frac{R_1 - R_2}{R_1 + R_2} \qquad g'_1 + g'_2 = \frac{2\,q}{1 + q^2}$$

$$Ro_m = \frac{R_1}{1 + g'_1} = \frac{R_2}{1 - g'_2}$$

$$Ro_m = \frac{R_1{}^2 + R_2{}^2}{R_1 + R_2} = R\ [1 + q^2]$$

$$g'_1 = \frac{q\ [1 - q]}{1 + q^2} \qquad g'_2 = \frac{q\ [1 + q]}{1 + q^2}$$

Ro_m is the limiting value for Ro, obtained when the torque on the axle is constant.

At any instant the wheel of radius R_1 runs with apparent radius of

$$\frac{R_1}{1 + g_1}$$

whence

$$(d\alpha - d\theta)\,\frac{R_1}{1 + g_1} = dx \quad . \ . \ (1)$$

since $d\alpha$ and $d\theta$ are contrary in sense, while the wheel having a radius R_2 runs with an apparent radius of

$$\frac{R_2}{1 - g_2}$$

whence

$$(d\alpha + d\theta) \frac{R_2}{1 - g_2} = dx \quad . \quad . \quad (2)$$

since $d\alpha$ and $d\theta$ are rotating in the same sense.

$$dx = Ro\ d\alpha$$

Under these conditions we find :

$$Ro = \left(1 + \frac{d\theta}{d\alpha}\right) \frac{R_2}{1 - g_2}$$

$$= \left(1 - \frac{d\theta}{d\alpha}\right) \frac{R_1}{1 + g_1} = \frac{dx}{d\alpha}$$

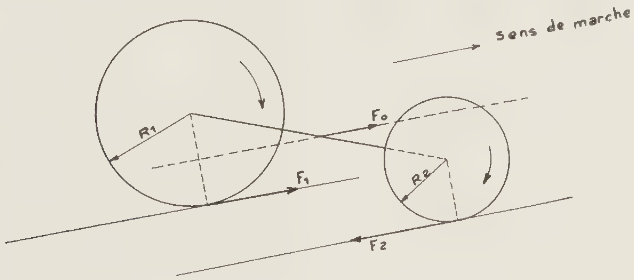


Fig. 2. — Equilibrium of a « dicone » moving at constant speed, without pivoting.
Sens de marche. = Sense of the motion.

Let :

$$Ro = R\left(1 + q^2 - 2\frac{d\theta}{d\alpha} q\right)$$

$$g_1 = \frac{(1 - q)\left(q - \frac{d\theta}{d\alpha}\right)}{1 + q^2 - 2q\frac{d\theta}{d\alpha}}$$

and

$$g_2 = \frac{(1 + q)\left(q - \frac{d\theta}{d\alpha}\right)}{1 + q^2 - 2q\frac{d\theta}{d\alpha}}$$

At every instant the wheel of radius R_1 (R_1 being $> R_2$) slips back in respect to the sense of the longitudinal motion of the unit dicone, it being subjected by the rail to a motive force (fig. 2).

$$F_1 = \frac{P}{2} K g_1$$

(P = weight of the unit dicone), while the wheel of radius R_2 slides forward, i. e., in the sense of the longitudinal motion of the unit dicone, it is subjected by the rail to a retarding force :

$$F_2 = \frac{P}{2} K g_2$$

The rolling movement of the dicone is thus impossible unless the latter is subjected to an external force Fo acting in the sense of its displacement.

$$Fo = (F_2 - F_1) = \frac{P}{2} K (g_2 - g_1)$$

The axle is likewise subjected by the rails to a pivoting couple having a moment

$$Cp = \frac{PK}{2} (g_1 + g_2) E$$

(2 E = distance between rails — i. e. gauge.)

We shall assume that this couple is balanced by an external couple which prevents the unit dicone from pivoting.

In addition, the axle is subjected to a torque couple of moment

$$C_t = \frac{P}{2} K g_1 R_1 = \frac{P}{2} K g_2 R_2$$

If we take into account a longitudinal displacement dx of the axle, the energy provided by the external force is

$$W_o = \frac{P}{2} K (g_2 - g_1) \, dx$$

by substituting dx by

$$R_o \, d\alpha = R \left(1 + q^2 - 2q \frac{d\theta}{d\alpha}\right) d\alpha$$

we get

$$W_o = PKq \left(q - \frac{d\theta}{d\alpha}\right) R \, d\alpha$$

a portion of this energy is dissipated in heat by the longitudinal pseudo-slips of the two wheels.

$$W_f = \frac{PK}{2} (g_1{}^2 + g_2{}^2) \, dx$$

$$= \frac{PK \, (1 + q^2) \left(q - \frac{d\theta}{d\alpha}\right) R \, d\alpha}{1 + q^2 - 2q \frac{d\theta}{d\alpha}}$$

$W_o - W_f = W_p$ increases the potential energy of the axle in torsion

$$W_p = \left(\frac{P}{2} K g_1 R_1 \, d\theta\right) 2$$

$$= \frac{PK \, (1 - q^2) \left(q - \frac{d\theta}{d\alpha}\right) R \, d\alpha}{1 + q^2 - 2q \frac{d\theta}{d\alpha}}$$

These relations show how each axle tends to nose when the diameters of the tread circles of their wheels are unequal.

The energy W_o supplied by the external longitudinal force applied to the axle is converted into heat partially by the longitudinal pseudo-slips. This is a motive force, it may be an inertia effect. The remaining energy is stored in the shape of potential energy in the axle which has a moment of inertia with respect to its axis, as also an angular torsional rigidity.

The forces of longitudinal friction give rise to a pivoting couple which generates the nosing motion when the axle is free to pivot on the track. In the course of this nosing movement, part of the potential energy of the axle is returned and is utilised to make good the energy which was converted into heat by the transverse pseudo-slips.

If in the course of the movement an excess of energy W_o is generated, this will be added to the kinetic energy of the axle during its traversing and rotational motions, and this damping effect then becomes negative so that the speed may increase indefinitely.

We will now examine the relative torsional movement of the axle $\theta = f(x)$ during the longitudinal displacement produced at constant speed. We shall denote the moment of inertia of half an axle by J and the corresponding angular rigidity by R.

Equations (1) and (2) lead us to the relation :

$$d\alpha\,(R_1 - R_2) = d\theta\,(R_1 + R_2) + 2R_1 g_1 d\alpha;$$

in addition equilibrium in torsion of the axle, gives us the equation

$$\frac{P}{2}\,Kg_1R_1 = R\theta + \frac{Jd^2\theta}{dt^2}$$

with $dx = R\omega dt$.

R represents the mean true radius of the wheels.

$$R = \frac{R_1 + R_2}{2}$$

Hence the torsional movement of the axle is determined by the equation :

$$\frac{d^2\theta}{dx^2} \times \frac{2JR\omega^2}{PK} + \frac{R\,d\theta}{dx} + \frac{2R\theta}{RPK} = \frac{R_1 - R_2}{R_1 + R_2} = q = g'$$

The resultant torsional couple applied to each wheel is

$$C_t = R\theta + \frac{Jd^2\theta}{dt^2} = R\theta + JR^2\omega^2\,\frac{d^2\theta}{dx^2}$$

We shall successively examine different cases of this rotation

a) R $= o$ *Independent wheels*

$$\frac{d\theta}{dx} = \frac{g'}{R}\left(1 - e^{-\frac{PKx}{2\omega^2 J}}\right)$$

and $$C_t = \frac{PK}{2}\,g'Re^{-\frac{PKx}{2\omega^2 J}}$$

The torsion couple on the axle is a maximum where the movement originates and diminishes rapidly as a function of the space.

b) R *has a finite value* and J $= 0$ (hypothetical case).

In this case

$$C_t = \frac{PKRg'}{2}\left(1 - e^{-\frac{2Rx}{PKR^2}}\right)$$

The torsion couple of the axle is zero when $x = 0$ and grows rapidly as a function of the distance. The space constant τ is in practice always small.

$$\tau = \frac{PKR^2}{2R}$$

c) R and J *have a finite value* (general case).

If $$JR > \frac{P^2K^2R^2}{16\omega^2}$$

the torsion couple will take the form

$$C_t = \frac{PKg'}{2}\left[1 - e^{-\lambda_1 t} \times \frac{2\lambda}{a}\sin ax\right]$$

with $$\lambda = \frac{PK}{4\omega^2 J}$$

$$a = \sqrt{\frac{16\ RJ\omega^2 - R^2P^2K^2}{16\ R^2J^2\omega^4}}$$

In this case C_t is a maximum when $X - 0$ and $X - \infty$.

This function $C_t = f(x)$ has a heavily damped harmonic motion.

If $$JR < \frac{P^2K^2R^2}{16\omega^2}$$

the torque couple will be in the form

$$C_t = \frac{PKg'R}{2}\left(1 + \frac{\lambda_1+\lambda_2}{\lambda_1-\lambda_2}\left[e^{-\lambda_1 x} - e^{-\lambda_2 x}\right]\right)$$

with

$$\lambda_1 = \frac{PK}{4\omega^2 J} + \sqrt{\frac{R^2P^2K^2 - 16RJ\omega^2}{16R^2\omega^4J^2}}$$

$$\lambda_2 = \frac{PK}{4\omega^2 J} - \sqrt{\frac{R^2P^2K^2 - 16RJ\omega^2}{16R^2J^2\omega^4}}$$

the pseudo-slip phenomena cannot be neutralized unless the moment of inertia J and the angular rigidity R of a half-axle are zero. It is possible to neutralise R by using axles mounted with loose wheels, on the other hand J cannot be got rid of. On the contrary, when it is a question of a driving axle, the moment of inertia J of a half-axle is greatly increased by the inertia of the revolving

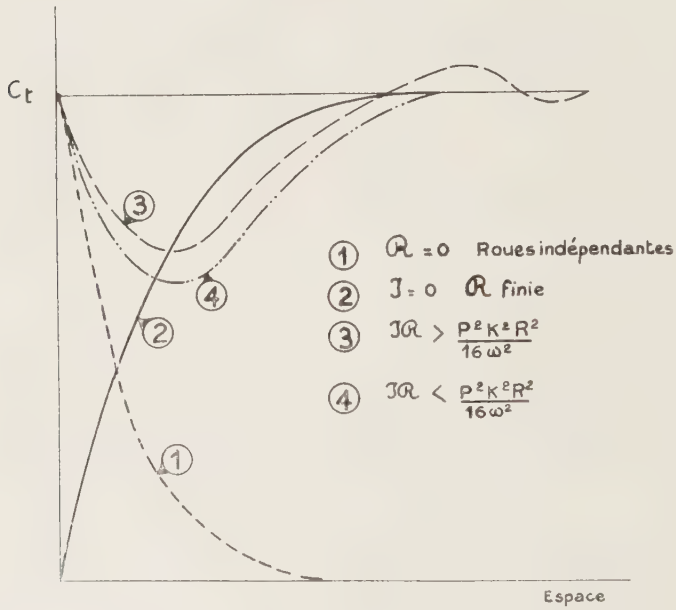


Fig. 3. — Variations of couple C_t applied to each wheel as a function of the space when R_1 R_2 and V are constant.
Roues indépendantes = Independent wheels. — Finie = Finite. — Espace = Space.

The torsion couple reaches a maximum for $x = 0$ and $x = \infty$. This function has a markedly aperiodic character.

We have shown in figure 3 the variations of function $C_t = f(x)$ for the different cases examined above.

These relations show that the pivoting couple applied to the axle as a result of masses forming parts of the driving gear.

This is why the use of axles with loose wheels is not an absolute cure against nosing, but it constitutes a great improvement, since the effect of angular rigidity is relatively greater than the effect of the moment of inertia.

Moreover, the curves in fig. 3, show that if we take into account the respective and practical values of the parameters J, R, P, K, we may assume that the frictional forces resulting from the pseudo-slip reach their maximum value instantly.

$$\frac{PKg'R}{2} = \frac{PKqR}{2}$$

which amounts to admitting that the space constant in torsion is zero.

Note. — We have allowed in the foregoing for the fact that the differences in the radii of the tread circles are slight enough to be compensated by pseudo-slip phenomena such as

$$\varphi = Kg'$$

$$\text{when } g' = \frac{R_1 - R_2}{R_1 + R_2}$$

This assumption is justified because the lateral play allowed by the track is always small.

We may enquire what would happen if

$$g' = \frac{R_1 - R_2}{R_1 + R_2}$$

were greater than the limit g_m of pseudo-slip (fig. 1) which fixes the adhesion φ_m of the wheel,

The slip $g' > g_m$ could only be compensated by superposing a true slip on the pseudo-slip.

In this case, in course of the forward motion of the axle, the torsion couple would reach the maximum value determined by the coefficient of adhesion φ_m and the maximum pseudo-slip g_m.

The slip g' then becoming greater than g_m, it could only be compensated by true slip, which would be accompanied by a reduction of the coefficient of friction between rail and wheel.

After the axle subjected to torsion has been released, it will again be subjected to a growing torque ultimately leading to true slip on each of the wheels and this phenomenon will be reproduced indefinitely. The axle would be subjected to torsional oscillations characterized by its natural pulsation a as a function of time frequency.

$$a = \sqrt{R/J}$$

This movement would be analogous to that produced by the slipping of a bow on a vibrating string. In this case the track would represent a double bow, while the axle would behave like a vibrating string.

C. Influence of the angle of inclination of the rail treads and of their radius of curvature on the apparent taper (conical shape) of the tyres.

In the course of chapter B above, we have assumed that the rails had a negligible thickness.

In reality the rails have their tread inclined at an angle of 1/20 towards the centre of the track. In addition the tread of the rail is curved to an arc of 60 mm radius for a chord of 22 mm.

Finally, it is shown that if an axle is displaced transversely by an amount y with respect to the axis of the track, the difference in the tread circles is slightly greater than 2 iy (i being the actual taper

on the tyres). In practice therefore it all fits in as if the tyres having a taper *i* were displaced on vertical rails of negligible thickness.

D. Examination of the swaying motion of a pair of wheels and axle (transverse and angular displacement) forced to move in a straight line at constant longitudinal speed and running on two parallel rails.

a) *Kinetic swaying motion.*

In the first place, we shall discuss the movement of a pair of wheels connected by a single axle (the tyres having a taper *i*) and moving longitudinally at a constant, but very slow speed V.

This motion is characterised by the kinetic sway of the wheels and axle, the radius of the tread circle is R when the centre of the unit (2 wheels and one axle) is situated on the axis of the track and the distance between the rails (gauge) is 2 E.

y is the ordinate of the centre of the unit with reference to the centre line of the track. It is taken as positive in the upward direction.

β is the angle made between the normal to the axis of the unit and the axis (centre line) of the track, reckoned positive in accordance with the trigonometrical conventions as shown in fig. 4.

The transverse displacement y of the centre of the unit produces for each wheel a pseudo-slip.

$$g = \frac{R_1 - R_2}{R_1 + R_2} \quad \text{now } R_1 = R + iy, \quad R_2 = R - iy$$

whence $$g = \frac{iy}{R}$$

This pseudo-slip creates an important pivoting couple. In order that the motion of the unit should preserve a kinetic character, it is necessary that the pseudo-slip $g = iy/R$ should be compensated by a pseudo-slip of opposite sign brought about by a reduction of the angle β.

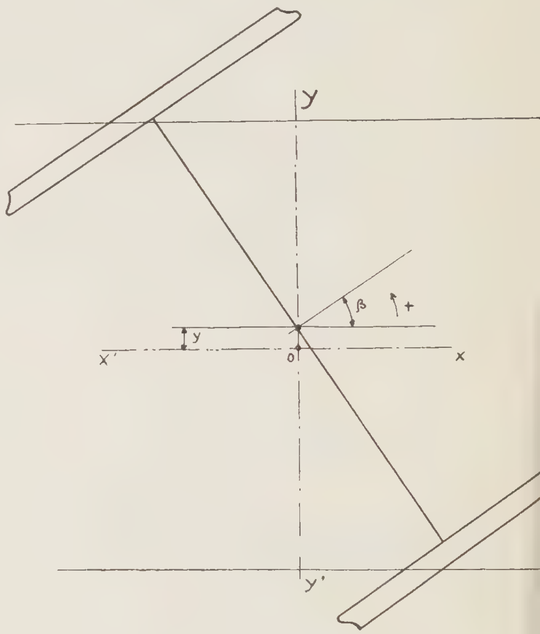


Fig. 4. — Study of the dynamic swaying motion.

If $d\beta$ is the variation of the angle between the unit and the track, the corresponding pseudo-slip is

$$E \frac{d\beta}{dx}$$

The kinetic swaying motion will be evident if in the course of the movement, each of the wheels rolls (turns) without a pseudo-slip and without producing any appreciable inertia reaction.

$$\frac{d^2y}{dt^2} \text{ and } \frac{d^2\beta}{dt^2}$$

must be negligible, so that V will be very small.

The movement may thus be stated by the equation :

$$\frac{iy}{R} + E\frac{d\beta}{dx} = 0; \text{ hence in this case } \beta = \frac{dy}{dx}$$

whence $$E\frac{d^2y}{dx^2} + \frac{iy}{R} = 0$$

y takes the form

$$y = A\sin\mu x + B\cos\mu x \quad \text{being } \mu = \sqrt{\frac{i}{ER}}$$

The transverse movement is characterised by a spatial wave length

$$L = 2\pi\sqrt{\frac{RE}{i}}$$

the angular motion of the unit is such that β is in advance of $\pi/2$ by its ratio to y.

The kinetic sway of the unit is such that at each moment it turns about its instantaneous centre of rotation in such a way that each of the wheels rolls with a negligible pseudo-slip.

The radius of curvature of the trajectory of the centre of the unit is

$$\rho = -\frac{ER}{iy} \text{ whence } E\frac{d^2y}{dt^2} + \frac{iy}{R} = 0$$

b) *The dynamic sway.*

When the longitudinal speed V of the unit is appreciable, the couples and forces due to the pseudo-slips must be balanced at every instant by couples and forces of inertia.

If M is the mass of the unit and I its moment of inertia with reference to a vertical axis at right angles to the track passing through its centre of gravity, the conditions for equilibrium of the unit are expressed by :

$$-PK\left[\frac{dy}{dx} - \beta\right] = M\frac{d^2y}{dt^2}$$

for the forces.

The transverse slip is, in effect, $dy - \beta dx$ and the pseudo-slip.

$$g = \frac{dy - \beta dx}{dx}$$

and by

$$-PKE\left[\frac{iy}{R} + E\frac{d\beta}{dx}\right] = I\frac{d^2\beta}{dt^2}$$

for the couples, since at every instant the longitudinal pseudo-slip for each wheel is stated by

$$\frac{iy}{R} + E\frac{d\beta}{dx}$$

By substituting $\frac{dx}{V}$ for dt we finally obtain the equations

$$-PK\left[\frac{dy}{dx} - \beta\right] = MV^2\frac{d^2y}{dx^2}$$

$$-PKE\left[\frac{iy}{R} + E\frac{d\beta}{dx}\right] = IV^2\frac{d^2\beta}{dx^2}$$

which leads us to the following differential equation, taking into account the fact that practically speaking $I = ME_2$

$$\frac{M^2V^4RE}{P^2K^2i}\frac{d^4\beta}{dx^4} + \frac{2REMV^2}{iPK}\frac{d^3\beta}{dx^3} + \frac{RE}{i}\frac{d^2\beta}{dx^2} + \beta = 0$$

If $V = 0$, we get the differential equation for the kinetic sway.

In the general case ($V > 0$) putting

$$m = \frac{PK}{2MV^2}, \quad n^4 = \frac{i}{RE} \times \frac{R^2K^2}{M^2V^4}$$

we can write the characteristic equation :

$$(1) \qquad X^4 + 4mX^3 + 4m^2X^2 + n^4 = 0$$

which may be written

$$X^2 [X + 2m]^2 + n^4 = 0$$

and can then be broken up into two equations of the second degree.

$$(2) \qquad X [X + 2m] + jn^2 = 0$$

$$(3) \qquad X [X + 2m] - jn^2 = 0$$

The roots of (3) are imaginary, being conjugate to those of (2) it suffices to work out the latter :

whence $\quad x = -m \pm \sqrt{m^2 - jn^2}$

but

$$\sqrt{m^2 - jn^2} = \pm \left[\sqrt{\frac{m^2 + \sqrt{m^4 + n^4}}{2}} - j\sqrt{\frac{\sqrt{m^4 + n^4} - m^2}{2}}\right]$$

$$x = -m \pm \sqrt{\frac{m^2 + \sqrt{n^4 + m^4}}{2}} \pm j\sqrt{\frac{\sqrt{n^4 + m^4} - m^2}{2}}$$

The roots include both real and imaginary terms. The function $\beta = f(x)$ is therefore represented by two harmonic functions having the same pulsation (beat).

$$\mu = \sqrt{\frac{\sqrt{n^4 + m^4} - m^2}{2}}$$

The term $a = -m + \sqrt{\dfrac{m^2 + \sqrt{n^4 + m^4}}{2}}$ characterising the counterdamping of the motion is always positive; it is zero for $V = 0$ and $V = \infty$ and passes through a maximum at a certain value of the longitudinal speed of the unit.

The angular movement of the unit will therefore take the form of

$$\beta = e^{-bx}\left[B \cos \mu x + C \sin \mu x\right] + e^{+ax}\left[D \cos \mu x + G \sin \mu x\right]$$

The movement diminishes rapidly as a space function

$$a, \beta = e^{+ax}\left[D \cos \mu x + G \sin \mu x\right]$$

with

$$\mu = \sqrt{\frac{P^2K^2}{8\,M^2V^4}\left[\sqrt{1 + \frac{16\,M^2\,V^4 i}{P^2K^2RE}} - 1\right]}$$

The length of the spatial wave characterizing the angular swaying motion of the unit is :

$$L = 2\pi\sqrt{\frac{8M^2V^4}{P^2K^2}\,\frac{1}{\left[\sqrt{1 + \frac{16\,M^2V^4 i}{P_2\,K_2\,RE}} - 1\right]}}$$

for $V = 0$ we again find

$$L = 2\pi\sqrt{\frac{RE}{i}}$$

(kinetic sway).

The transverse movement y of the centre of gravity of the unit is defined by the relation

$$(4) \qquad \frac{M\,V^2}{PK}\frac{d^2y}{dx^2} + \frac{dy}{dx} = e^{+ax}\,(D \cos \mu x + G \sin \mu x)$$

The solution of this equation shows that the function $y = f(x)$ which characterises the transverse sway of the unit appears in the form

$$y = e^{ax} \left[F \cos(\mu x - \varepsilon) + A \sin(\mu x - \varepsilon) \right]$$

The transverse motion lags behind the angular motion β.

Summarizing the foregoing, the sway motions of the unit (i. e., translation and rotation) are harmonic functions subjected to negative damping, so that the amplitudes of these movements increase indefinitely as a function of the space after the motion has been damped by a transverse displacement of the centre of gravity of the unit.

These movements are amplified because in the course of an elementary cycle, a discontinuous supply of energy is forthcoming, arising from a restitution or partial release of the potential energy accumulated in the form of a torque stress in the unit. This supply of energy is greater than that dissipated in the form of heat by the friction due to the transverse pseudo-slipping.

The source of this energy is represented by longitudinal kinetic energy of the unit (dicone) and in effect, by the source of energy which provides the force necessary for supporting the longitudinal speed V of the constant unit (dicone).

These sway movements which are due to the irregularities in the radii of the tread circles of the wheels on an axle indicate the character of the oscillations caused by stress release (relaxation).

When V and i (taper) increase, the anti-damping factor continues to increase, whereas when K (adhesion) and R increase, the anti-damping factor varies according to the value obtained for the coefficient γ.

The coefficient $\gamma = \dfrac{16\ M^2V^4i}{P^2K^2RE}$

at zero speed V, the transverse displacement y lags behind $\pi/2$ in proportion to the angular movement.

This lag tends to increase slightly with V, at least in the region of the usual speeds.

As an actual example, the curves in fig. 5 show the characteristics of the sway motion in a unit having the following particulars :

$K = 200 \quad R = 0.7 \quad E = 0.75 \quad i = 1/20$

They represent the longitudinal speed V in m/s, the speed in Km/hour, the length of wave L, the coefficient γ, the damping factor b and the (negative) damping coefficient a.

The different relations we have established above are based on the assumption that play in the track is infinite. In reality this play is small and on a straight run, the track appears of infinite length as on a billiard table.

Consequently a sway motion due to reflexion is superposed on a swaying motion due to stress release. Its effect is to reduce the length of the actual spatial wave to a value less than that which would result from a sway due to a stress release considered by itself.

On account of the transverse flexibility of the track and of each unit, the resulting sway motion acquires a cyclic movement of constant amplitude which might lead to characteristic dynamic instability.

CONCLUSIONS.

The use of tapered tyres combined with the slope of the rail treads is consi-

dered by the authors of this arrangement as representing an element of stability in their trajectory since the transverse holds good both kinetically and statically.

In order that such arrangement should operate dynamically, the swaying motion

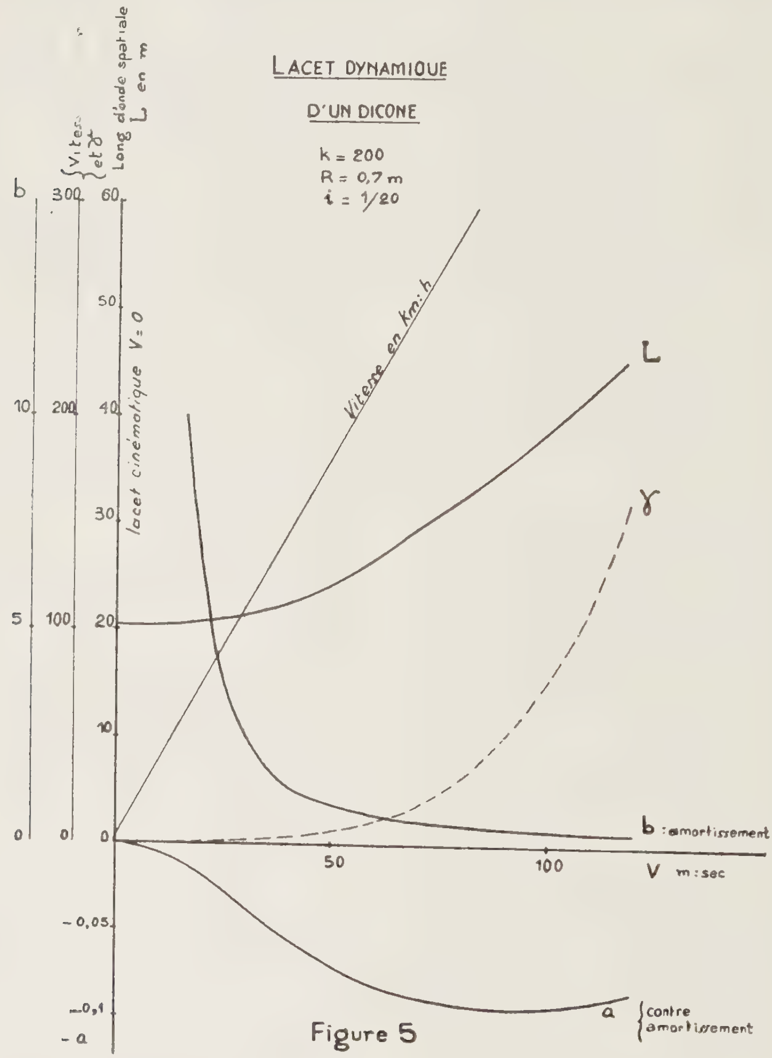


Figure 5

motion of the units (wheels and axle) tends on principle, to bring the centre of gravity of each of the axles into the centre line of the track. This argument should itself be exclusively controlled by a strong damping coefficient.

The foregoing discussion shows, however, that this motion is on the contrary

strongly affected by a negative anti-damping force, hence the standard arrangements adopted in the design of the permanent way and of the shape of the tyres lead to the presence in each axle of a factor of dynamic instability (fig. 6).

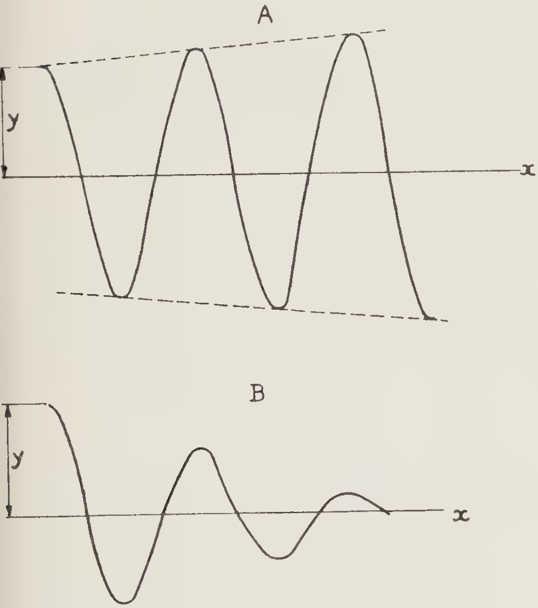


Fig. 6.

A = True unstable swaying motion (Relaxation).
B = Swaying motion as it should be in order to secure stability.

Methods enabling the sway due to relaxation to be suppressed or to diminish its effect.

a) *Suppression of sway due to relaxation secured by using axles having wheels coupled in rotational order and fitted with cylindrical tyres (i. e., without taper).*

In this case the taper i is zero and the transverse sway is suppressed.

The equations for equilibrium of forces and couples produced by the pseudo-slip (see p. 11) now become

$$MV^2 \frac{d^2\beta}{dx^2} + PK \frac{d\beta}{dx} = 0 \quad \text{(couples)}$$

$$MV^2 \frac{d^2y}{dx^2} + PK \frac{dy}{dx} = PK\beta \quad \text{(forces)}$$

We shall grant that following a motion of « reflexion » by a unit (axle and 2 wheels) on a rail we have

$$\frac{dy}{dx} = a_1 \text{ and } \frac{d\beta}{dx} = b_1$$

The rotary motion of the unit is characterized by

$$\frac{d\beta}{dx} = b_1 \, e^{\frac{-PKx}{MV^2}}$$

this motion is therefore heavily damped.

The movement of translation (skidding) is likewise damped since it obeys the relation

$$\frac{dy}{dx} = e^{\frac{-PK}{MV^2}} \left[a_1 - b_1 x \right]$$

Consequently the exclusive use of axles carrying cylindrical tyres (non taper) and running on rails having a horizontal tread, would lead to excellent conditions since the sway motion due to relaxation would be completely suppressed while the sway due to reflexion would be heavily damped by the friction due to the pseudo-slip (skidding) both transverse and longitudinal.

In actual practice and taking into consideration the actual state of the tracks, one can only run axles carrying cylindrical tyres on rails having their tread inclined at an angle of 1/20.

Experience has taught us that such an

arrangement will only be efficacious during a limited period, because the tyres quickly wear themselves down by friction to the shape of the rails. This wear results in effect from the combined action of numerous axles (different vehicles) having taper tyres running on rails having their treads inclined at 1/20.

b) *Reduction of the sway due to relaxation, secured by use of axles fitted with taper (conical) tyres and wheels rotating independently (loose wheels).*

This arrangement is efficacious so far as the importance of the sway due to relaxation goes. Nevertheless this does not provide a complete solution of the problem, since the taper on the tyres gives rise to friction stresses applied longitudinally on the rails when the speed of rotation of the loose wheels varies.

These forces are a function of the true moment of inertia of the wheels and of the apparent moment of inertia of the transmission gears and of the motor components.

However, the use of loose carrier wheels suppresses the damping of rotational movements (consequent on the sway due to reflexion) by neutralizing the longitudinal forces due to pseudo-slip resulting from these movements.

Consequently, it is necessary to supplement the use of loose carrying wheels by a self-centering wobble-damped gear placed between the units and members which they operate in such manner as to secure for this device all the advantages gained by the use of cylindrical tyres.

c) *Possibilities of reducing the sway caused by relaxation when each unit is provided with pairs of rotating wheels and with tapered tyres.* (Standard axle.)

In effect the railway vehicles contain more or less complex combinations of units (pairs of wheels and axle) with translation of motion by means of chassis (underframes).

Each of these underframes tends to carry out a swaying movement due to relaxation and this combined with a sway due to reflexion, may act as exciter or produce a forced oscillation according to the different natural frequencies possessed by all railway rolling stock, which consists essentially of combinations of weight and springs.

In the absence of an arrangement governed in principle for suppressing the causes (i. e., coning of tyres or rigidity in torsion of the axles) which produce the swaying movements of relaxation, it is possible substantially to reduce the effects :

a) by endeavouring to prevent the pseudo-slipping from producing resonance with the free oscillations of vehicles except at very low speeds of the latter (dynamic damping);

b) by providing joints between the principal elements of railway vehicles e. g., chassis (underframes), body, axles, etc., and components providing real damping which tends to neutralize the anti-damping factors which characterise the swaying motions due to relaxation, considered independently;

c) by seeking arrangements to connect the various axles which tend to a direct reduction of the anti-damping which characterizes the relaxation sway considered independently. Such arrangements should lead to an increase (real or apparent) of the rigid wheelbases, thus reducing the relative angular displacements of the various elements contained in railway vehicles.

[621 .337]

Individual axle drive.

Mechanical systems used on electric locomotives and railcars, with an indication of the results obtained in service on railways of all kinds,

(Continued)*

by ADOLPHE-M. HUG,

Consulting Engineer, of Thalwil (Zurich), Switzerland.

SUPPLEMENT. — APPENDIX.

(Continued)

Types of mechanism which have been introduced, or first described, since this survey was commenced in 1947.

N. B. — *This supplement completes, on the one hand, the author's work dated 1932/33 on the Individual axle drive (Commande individuelle des essieux), and on the other hand that published serially in the* Bulletin of the International Railway Congress Association, *Nos. of September, October and December 1947, February, April, July, October and November 1948, January 1949.*

The subject-matter is, therefore, as far as possible complete up to the Summer of 1949.

Concerning Chapter V.

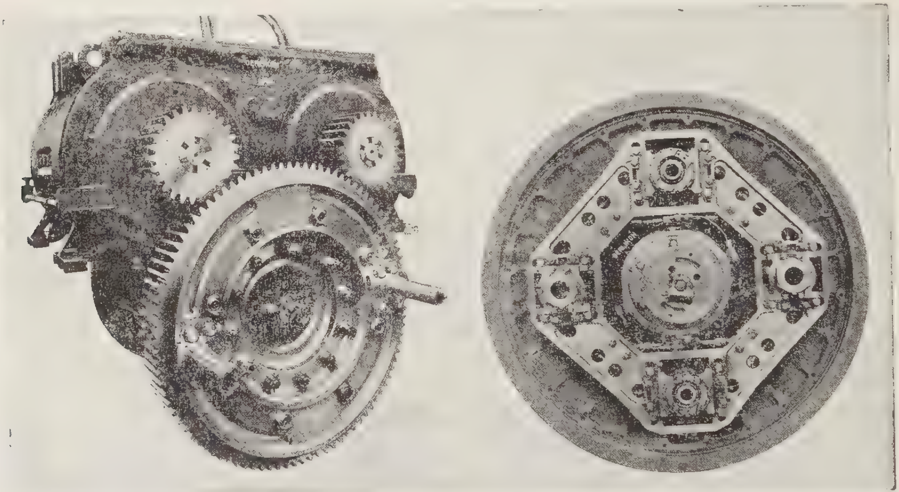
DRIVING MECHANISMS BASED ON THE OLDHAM JOINT.

A design was applied in 1934, which we have so far omitted to mention. This was the mechanism fitted to the $2\text{-}D_0\text{-}2$ locomotives, Nos. 701 and 702, of the « Orléans P-O », now SW Region (P-O-Midi) of the French SNCF [208]. These locomotives have an outer appearance very similar to fig. 22.

(*) See *Bulletin of the International Railway Congress Association*, Nos. of September, October and December 1947, pp. 823, 885 and 999 respectively, Nos. of February, April, July, October and November 1948, pp. 73, 227, 403, 591 and 661 respectively, January, May and November 1949, pp. 71, 379 and 775 respectively.

(208) See *Revue Générale des Chemins de Fer*, Paris, April 1935, p. 423 and figs. 9 to 11, Chapter 1 (Transmissions), of « Progress in mechanical equipment of electric locomotives ». — *Zeitschrift des Vereins Deutscher Ingenieure, ZVDI*, Berlin, 11th. Aug., 1934, K. SACHS. — *Bulletin Oerlikon*, Zurich, No. 167/168, 1935, pp. 911-914 (7 figs. and diagram).

This mechanism was designed and manufactured by the « Compagnie Générale de Construction de Locomotives », — Batignolles-Châtillon, Paris (Nantes Works); it is related to the former Oldham joint, under which title have been grouped all the mechanisms described in Chapter V. The electrical equipment was supplied by the French Oerlikon Works (Ornans, Doubs).



Cliché Oerlikon.

Fig. 357. — Oldham joint mechanism, 1934, used on the 2-D_0-2 (2-B_0-B_0-2), Nos. E.701 and 702 of the Orleans (French) Railways, afterwards PO-Midi and SW Region, SNCF. On the left are the two motors and their pinions engaging the gear wheel with two driving pivots; on the left an exterior view of the mechanism mounted against the axle (casing removed, see fig. 358).

Fig. 357 shews this mechanism; on the left is the hollow shaft with twin motors and gears and on the right, is a view of an Oldham joint, with the case removed, mounted against the wheel. Fig. 358 is an oblique view of the mechanism mounted on the axle.

The gears are unilateral, with resilient gears (coil springs, working by compression under the geared rim, cf. figs. 7 and 278); the driving mechanism connecting the hollow shaft and the axle is bilateral. The Oldham joint is arranged against the outside of the driving wheels and is protected by a cover plate fitted to the outer face of each driving wheel [see fig. 1 of the publication mentioned at the end of note (208)].

The arrangement of this mechanism may be described as follows :

The twin electric traction motors are fixed to the locomotive frame; their pinions engage with one of the two plates of a hollow shaft fitted over the axle (see fig. 358). Springs are mounted in the pinion as well as the geared rim, to damp the shock transmitted to the gears and to provide a flexible transmission of the motor couple to the hollow shaft, which rotates in the bearing provided *for*

this purpose in the casing of the twin motors. Each plate on the hollow shaft has two pins with spherical heads, placed diametrically opposite, which can move transversally on the spherically-shaped pivots, as shewn on the left of fig. 357. The two pairs of pivot pins connected to the hollow shaft and two to the driving wheel. All parts subject to friction are enclosed. Lubrication is effected by means of a separately mounted pump (see fig. 358 and text thereto), so that the lubricant is suitably applied to all surfaces subject to fric-

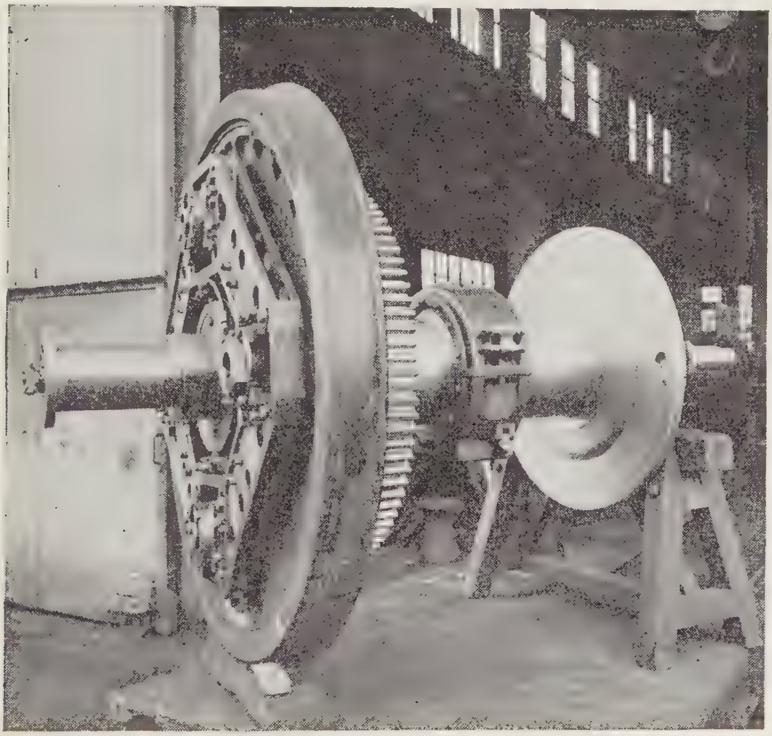


Fig. 358. — View of the axle of fig. 357 (right-hand side) the opposite wheel and mechanism being removed. At the end of the hollow shaft can be seen the disc bearing on its outer face the same driving pivots as on the gear wheel (fig. 357, left). In the centre of the hollow shaft is the housing of the worm-operated drive for the oil pump.

Photo Oerlikon.

engage in sockets in the four angles of a square frame which forms a kind of intermediate drive (a form of floating ring), the whole arrangement constituting an Oldham coupling, which may be described in a general way as follows:

The coupling therefore consists of a movable frame, of steel, with four bearing points set at 90°, two of which are

tion. The casing provides protection from dust thrown up in braking. With this coupling, the driving axles have freedom of movement in all directions in relation to the frame. The general arrangement plan of this form of drive is shewn in figs. 9 to 11 of the publication mentioned at the beginning of note ([208]). The lubrication of all parts

of this transmission naturally plays a beneficial part, and a description of its method of operation has just been given.

To avoid skidding of any axle, either at high speeds or when starting to run, each of the two trial locomotives, Nos. 701 and 702 (P-O), is provided with a device for avoiding skidding, one is mechanical (No. 701) and the other electric (No. 702). On locomotive No. 701, the pinions of the two motors 1 and 2 on the one hand, and 3 and 4 on the other, have been fixed by means of a non-resilient gear wheel connecting them in pairs ([209]). The similarity will be noted to the Als-Thom mechanism shewn in figs. 23 to 29 and described on the corresponding pages. The second locomotive, No. 702, is not provided with these two intermediate gear wheels; they

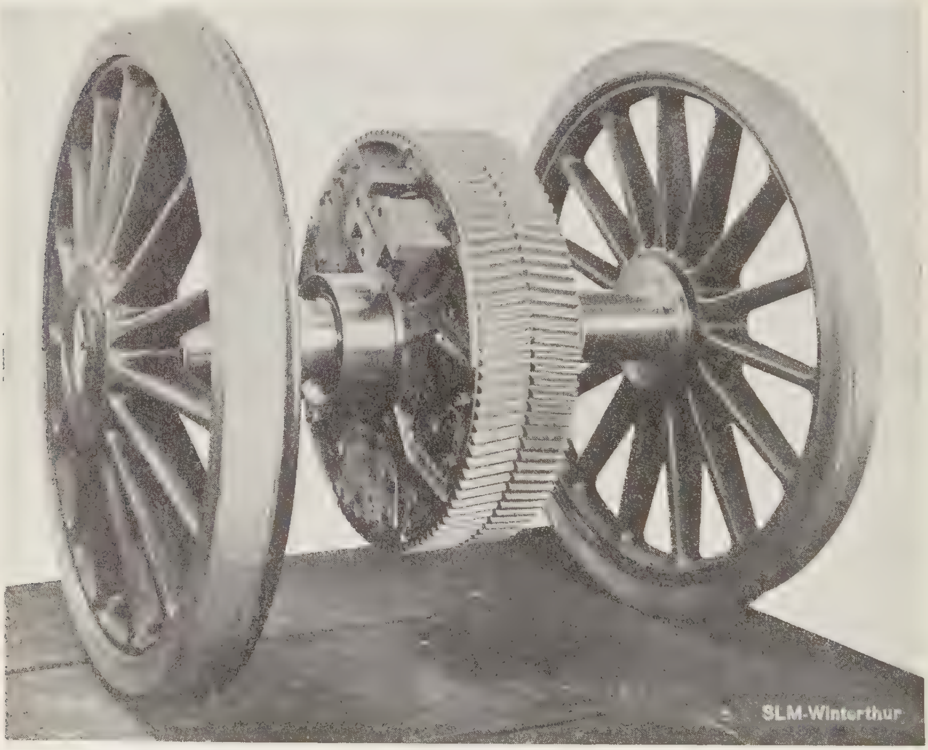


Photo SLM.

Fig. 359. — Driving axle of Netherlands NS electric locomotives, series 1001, shewn in figs. 234-237. The springs can be seen in one of the five transmission elements, partly emerging from its socket. Cf. figs. 235, 360 and 361.

([209]) French patent No. 710963 and Swiss No. 158422. — See fig. 2 of third publication mentioned in note ([208]).

are replaced by an anti-skid device fitted on each driving axle.

As regards the behaviour of this form of mechanism, it can be said that it has been very good, but the lubrication is too complicated and too expensive in operation, so that it has had no further application.

With regard to the series 1001 locomotives, type 1A-AA-A1, of the *Netherlands State Railways, NS,* described on the pages with figs. 228 to 238 (see figs. 234-237), fig. 359 shews a view of a fully-fitted axle with the transmission mechanism mounted on the end of the central hollow shaft and with the geared rim in position. Fig. 360 shews the axle with the five arms (cf. figs. 130, 136 and 137 of **Cde. indiv.**, and 218, 219, 230-232 of this series).

The whole arrangement, in elevation and sections, is shewn in fig. 361, from which can be seen the various details. It will be noted that it is, in fact, derived, with certain improvements, from the « universal » Wintherthur (SLM) drive, described in the text alongside fig. 231. In addition, it may be described exactly similarly to the floating rings dealt with below in connection with the single-phase locomotive No. 6051, type C_0-C_0, of the SNCF. Compare also with the mechanism of figs. 357 and 358; the same basic principles will be noted.

In the meantime, the first of the series 1001, Netherlands, locomotives, were placed in service on the NS towards the end of 1948 and appear to be giving satisfaction ([210]). A transverse section of one of these locomotives, through one of the driving axles (see fig. 234), is similar to that of fig. 218, apart from equipment and fittings for DC instead of single-phase, and the new mechanism. Fig. 362 shews locomotive

Photo SLM.

Fig. 360. — Axle shaft of fig. 359 with five-legged spider. Cf. figs. 359 and 361, as well as those mentioned in the text, regarding the old SLM « universal » drive, with two driving arms without springs (springs fitted only in the geared rims of the pinions).

([210]) See *Spoor- en Tramwegen*, The Hague-Utrecht, 30th. Dec. 1948, pp. 421-428, 8 figs., « De nieuwe serie NS 1000, 4 500 pk elektrische sneltreinlocomotief voor gemengd sneltrein/goederendienst », C. E. DOOWES-DEKKER. The first three locomotives of this series, Nos. 1001-1003, were built in Switzerland (Oerlikon and SLM); the others, Nos. 1004 to 1010, in the Netherlands, the mechanical parts in the Utrecht works of the Werkspoor Co., the traction motors by the « Electrotechnische Industrie Smit », of Slikkerveer-Rotterdam, and by the Heemaf Works, Hengelo. The driving mechanism and epuipment for the whole series, however, was provided by Oerlikon and SLM-Winterthur from Switzerland. — With regard to fig. 362, same review, 13th. Jan. 1949, pp. 2 to 7, steam heating brake vans, series 158951-158960 of the NS, 8 figs., W.-R.-G. v. D. BROEK.

See also *International Railway Congress Bulletin*, March 1949, figs. 24, 37 and 41 (pp. 254/46, 270/62 and 274/66), report on Question II (Enlarged meeting at Lisbon, 1949), Electric locomotives for express trains.

Also, in connection with note ([135]), *Railway Gazette*, August, 1948, and *Ingegneria Ferroviaria*, Rome, Jan. 1949, pp. 75 and 77, 3 figs.

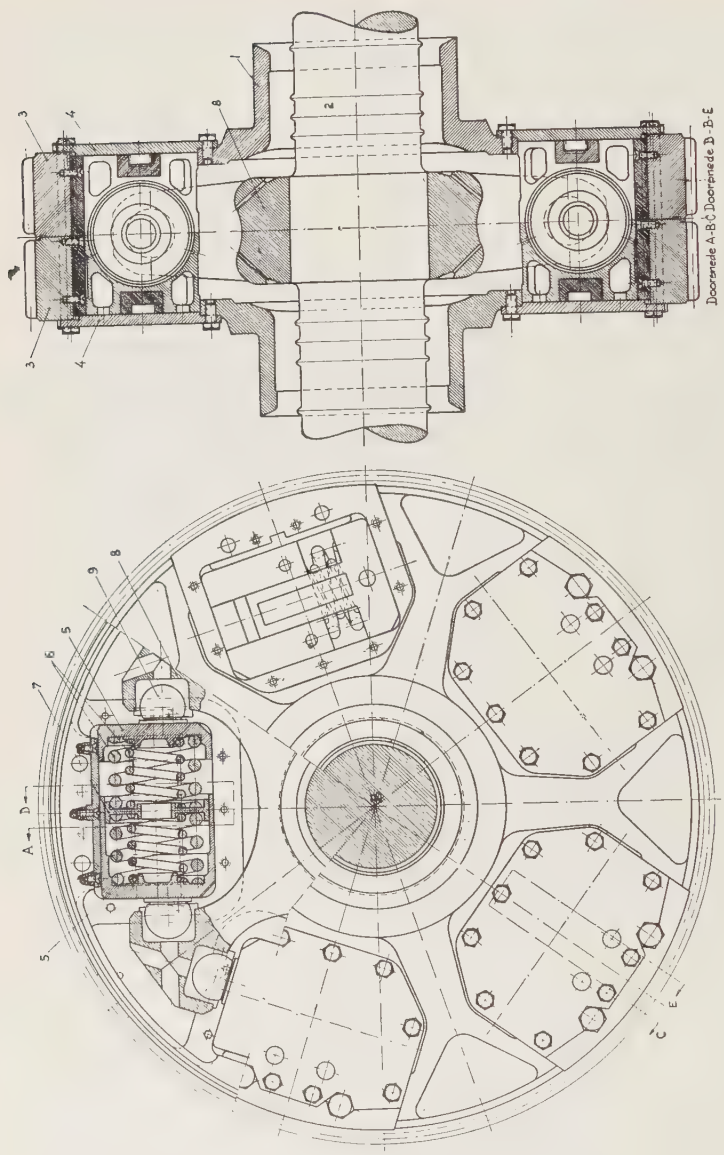


Fig. 361. — SLM-Winterthur mechanism, improved type (5 arms and springs) of NS locomotives, series 1001, type 1A-AA-A1, in elevation and section (cf. fig. 235, 359 and 360).

Cliché *Spoor- en Tramwegen* (from SLM plan).

1. Hollow shaft with tho central stub arms, carried in bearings fixed to the locomotive frame.
2. Axle shaft of fig. 360.
3. The twin geared rims oblique V teeth.
4. Spring chamber cover.
5. Couples, containing two pairs of springs 6 and dividing plate 7.
8. Steel casting, comprising hub and five driving arms, fixed on axle 2.
9. Spherical bearings for the couples 5, set in sockets at the ends of the arms 8.

(Doorsnede = section.)

No. 1001 hauling a test train, with steam heated brake van, standing at a station [see end of note (210)].

With reference to the prototype locomotive No. 6051 of the *French SNCF* — for single-phase, 20 kV, industrial frequency, shewn in fig. 238 (which does not, however, shew the final arrange-

Cliché *Spoor- en Tramwegen*. (Photo NS).

Fig. 362. — Electric locomotive No. 1001 of the NS, figs. 234-237 (fitted with mechanism figs. 359-361) attached to test train with steam heating brake van.

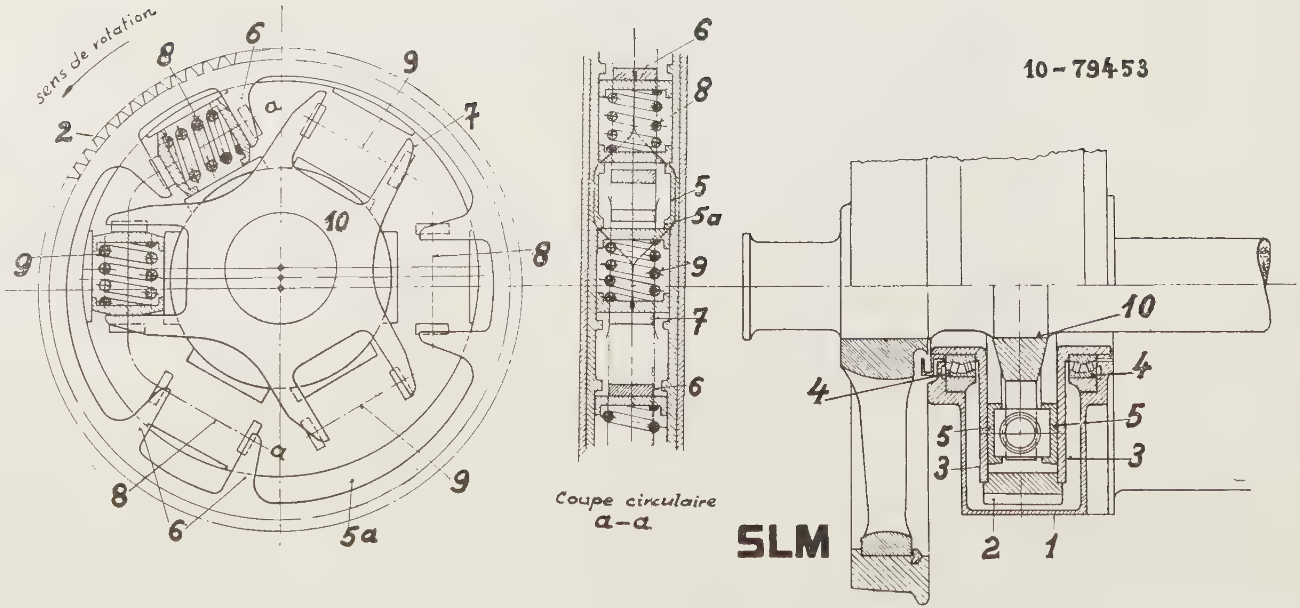
ment) and mentioned at the end of Chapter V, — fig. 363 is included to give a diagrammatic elevation and section of the driving mechanism which is described as follows [211] :

This drive comprises in principle a certain number of springs arranged tangentially inside the gear wheel, and fixed by means of a *suitable* device to the wheel and to the driving arms fixed to the axle. Whilst this may have some of the characteristics of a flexible drive, it is partly derived, as already stated, from the SLM « universal » drive, and has been designed for ease of manufacture.

The gear wheel is composed of three main parts, i.e. the geared rim 2 and the two lateral discs 3. These two discs 3 are extended towards the outside of the wheel by sleeves, on which rest the roller-bearing bodies which retain the wheel assembly within the gear case 1. The latter, of robust construction, is fixed to the bogie frame. It can be used as a motor support on the drive side.

The transmsision of the motor couple

[211] See *Railway Gazette*, 8th. Oct., 1948, pp. 407-409, 3 figs. (fig. 1 does not give the final form, cf. fig. 364), « Single-phase 50-cycle locomotives for France ».



Plan SLM.

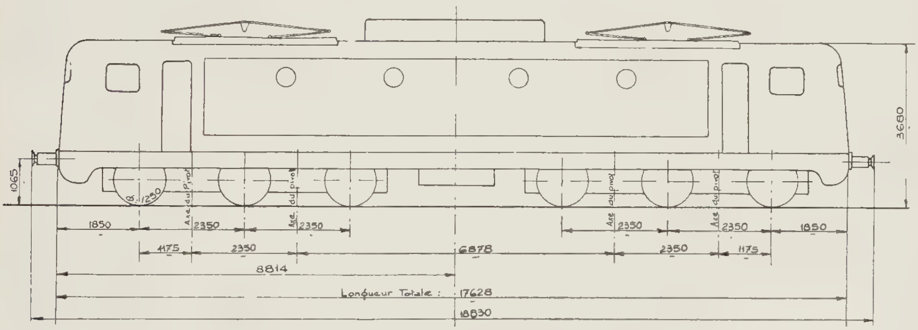
Fig. 363. — Diagram of new mechanism with floating ring, derived from the Winterthur « universal » (Oldham joint class) drive, applied with some modification to the C_0-C_0 locomotive No. 6051 (fig. 238, tentative arrangement) SNCF (France), as well as to NS locomotives, series 1001, type 1A-AA-A1 (Netherlands) (figs. 234-237, 359-362). For description of details, see text.

is effected by the geared rim 2, or rather by the forked pieces 6, on the two floating rings 5, through the flexible units 8, then on the arms 7 of the driving unit 10, through the flexible units 9, the construction of which is exactly similar to that of the units 8. The transmission of effort from the flexible elements 8 to the rings 5 is by means of the lateral blocks *5a*. This point is illustrated in the section *a-a*.

In cases where the gear wheel is not located at the same height as the axle, the difference in height is taken up by compression of the various resilient components, the floating rings occupying a constant middle position, independent of the angular position of the drive.

It may be remarked that the whole of the flexible elements corresponds to an elasticity in parallel with the suspension springs on the axle. This, however, shews no obvious disadvantages, since the characteristic of the additional resilience remains constant and so has no ill effect on the running of the vehicle (or of the bogie). It may also be noted that the springs 9 work in series with the springs 8 and should consequently transmit double the effort with a compression less than that of the similar flexible elements so far used. Fig. 363 shews a drive with six flexible elements, but having regard to the diameter used, it can be increased to eight or more.

Lubrication of the different parts is assured by a system of pockets and channels which collect and lead to the required points, the oil thrown off the gears on to the housing. Suitable joints are provided at the required points.



Cliché *Economie et Technique des Transports* (from Alsthom plan).

Fig. 364. — Prototype of SNCF single-phase locomotive, type C_0-C_0, No. 6052 (Als-Thom) 50-cycle, industrial frequency, 20 kV contact line. Cf. fig. 11, p. 241, *International Railway Congress Bulletin*, March, 1949.

This mechanism appears to have a considerable future interest, but it can only be judged after some years' experience on various types of locomotives and railcars.

It should be noted that the dimensioned sketch in fig. 238 does not shew the final form of the prototype SLM-Oerlikon locomotive No. 6051-SNCF, which has still to be finally decided and will no doubt be similar to fig. 364, the prototype Als-Thom locomotive No. 6052-SNCF. It will be recalled that these two

locomotives, as well as the S-W (« Le Matériel Electrique », Schneider-Westinghouse, Paris) prototype No. 6053-SNCF, type B_0-B_0-B_0, with nose-suspended motors, are for single-phase, industrial frequency, current, of a line tension of 20 kV [see note (136)].

As we have described in this Supplement, in the remarks on Chapter III, the new bogie with two pivots of the French SNCF locomotives Nos. 7001/2 (c.c.), a dimensioned sketch of which is given in figs. 11, p. 241/33, and 16, p. 246/38 of the *International Railway Congress Bulletin*, March 1949, Report, « Express electric locomotives », Lisbon, 1949, and 6052 (single-phase, 50 cycles) all C_0-C_0 type, built by Als-Thom, we shall describe here also the C_0 bogie (SLM-Winterthur) of the above mentioned prototype locomotive No. 6051, Oerlikon-SLM. Fig. 365 shews diagrammatically, elevations, plan, transverse and part sections and the arrangement of the motors and body bearers. The bogie may be described as follows :

The body rests directly on the double body springs 11, via the bearing 10. The springs are borne by two cross-members 8, one of which links one of the leading ends of the two pairs of springs and the other the trailing ends. These cross-bars are themselves suspended on the bogie through the vertical hangers 12. The lateral body bearers on the bogies are thus supported by the springs 11; these are connected to the body by the bearing 10 and linked to the bogie by the crossbars 8 and the hangers 12.

The longitudinal connection between body and bogies is by means of the bogie pivot 4, fixed in the longitudinal 14

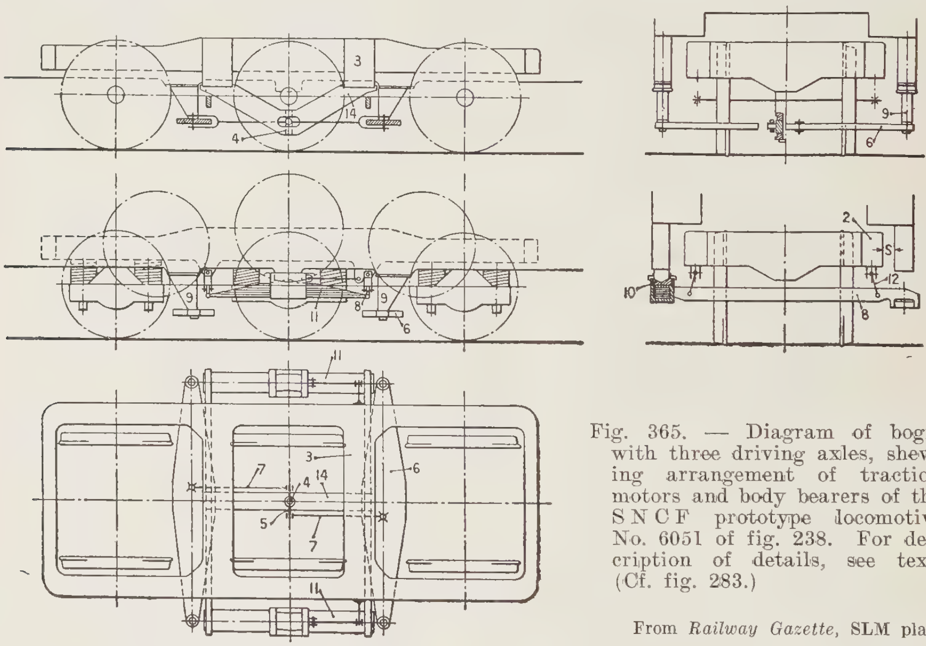


Fig. 365. — Diagram of bogie with three driving axles, shewing arrangement of traction motors and body bearers of the S N C F prototype locomotive No. 6051 of fig. 238. For description of details, see text. (Cf. fig. 283.)

From *Railway Gazette*, SLM plan.

which joins the two intermediate bolsters 3 of the bogie frame, between which is placed the central motor. This pivot carries the equalisor 5 which is connected to the two body bolsters 6 by the longitudinal rods 7. Owing to the presence of this equalisor 5, the tractive effort is distributed equally between the two bolsters 6 without in any way interfering with the lateral free play between body and bogies. This play is limited to a value « S » by the blocks 15, between the bogie solebars 2 and the body solebar.

This body arrangement also allows a rapid lifting of the body, as it is sufficient for this purpose to unscrew the bolts which hold the bolsters 6 and the body supports 9. In addition, it provides a simple transmission of vertical loads which remain wholly within the region of the plan of the wheels and the side carrying walls of the body; the transfer of the tractive effort is such that the parts concerned may be of adequate dimensions and suitable form. Finally, the lateral frictional support provides a useful damper for rotary movement of the bogies in relation to the body.

Photo Brown Boveri.

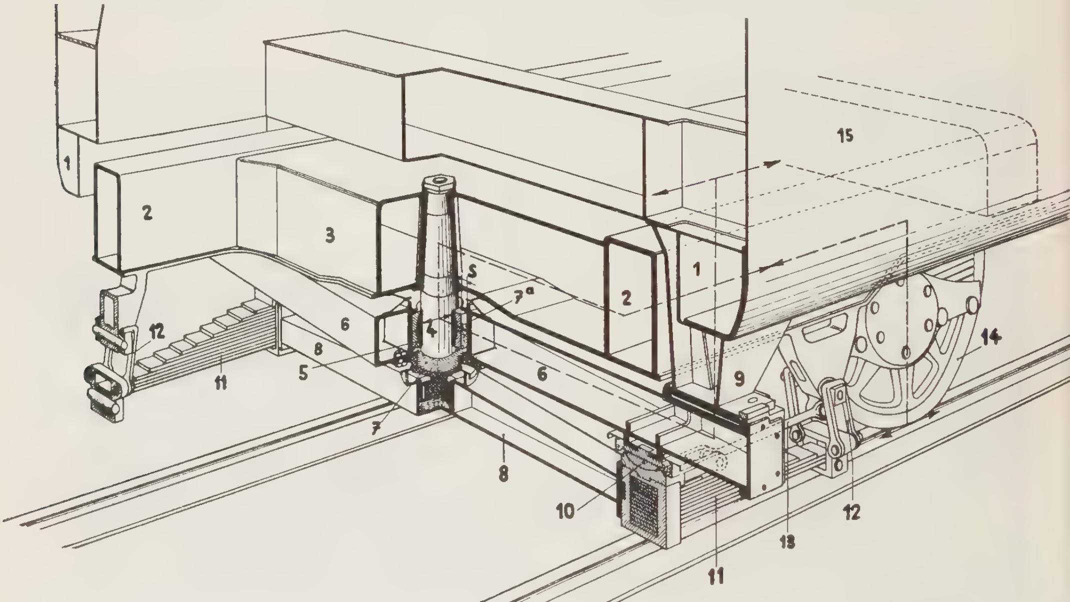
Fig. 366. — B_0-B_0 locomotive No. 251 of the Swiss BLS; Brown Boveri steel disc drive, on winter service on the Lötschberg line. The locomotive and bogies are the same as those in figs. 244, 247 and 248 of this series of locomotives.

Concerning Chapter VI.

DRIVING MECHANISMS WITH CARDAN JOINT HOLLOW SHAFT AND FLEXIBLE STEEL DISCS OR QUADRILATERAL LAMINATED OR PLATE COUPLING.

We have, in Chapter VI, dealt with some of the existing mechanisms, and we will now deal with the remainder, several of which have not yet been used, or, up to the end of 1948, have not been finally settled as regards their arrangement.

Firstly, let us return to some of the constructional details of the B_0-B_0 locomotives, series 251, of the Swiss Bernese Alps, Bern - Lötschberg - Simplon, BLS ([212]), already mentioned on many



Plan SLM. Cliché SBZ-BLS.

Fig. 367. — Diagram of suspension of BLS locomotives, figs. 244, 247, 248 and 366. (Cf. fig. 163.)

1. Hollow solebar of frame of locomotive body.
2. Hollow solebar of bogie frame.
3. Bogie middlebearer.
4. Bogie pivot, keyed at the upper part to the bogie middlebearer 3, and turning at the bottom part in the pivot 7 set in the body cross beam 6.
5. Spherical oilway for pivot 4.
6. Hollow body cross beam on which rest the body supports 9.
7. Spherical spring driving pivot.

7a. Oil level.

8. Connecting bar of laminated springs.
9. Body bearing shoe on cross beam 6.
10. Lateral bearing arrangement with oil bath.
11. Laminated body bearing springs.
12. Vertical spring links.
13. Longitudinal retaining bar of body springs 11.
14. Driving wheel.
15. Leading headstock of bogie frame.

S = lateral play of body suspension = 2 × 30 mm.

([212]) A relevant article by F. GERBER was due to be published during the summer of 1949 in the *Revue Polytechnique Suisse SBZ*, Zurich, cf. note ([140]). — See also *International Railway Congress Bulletin*, March, 1949, p. 240/32 and figs. 9 and 14 (Report « Express electric locomotives », Lisbon, 1949).

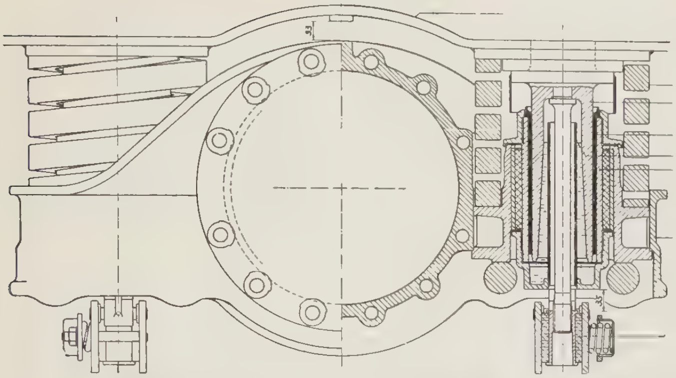


Fig. 368. — Guides for roller bearing boxes in figs. 244, 247, 248, 366 and 367 of the BLS with oil dampers (see driving wheel 14 in fig. 367).

Cliché SBZ-BLS.

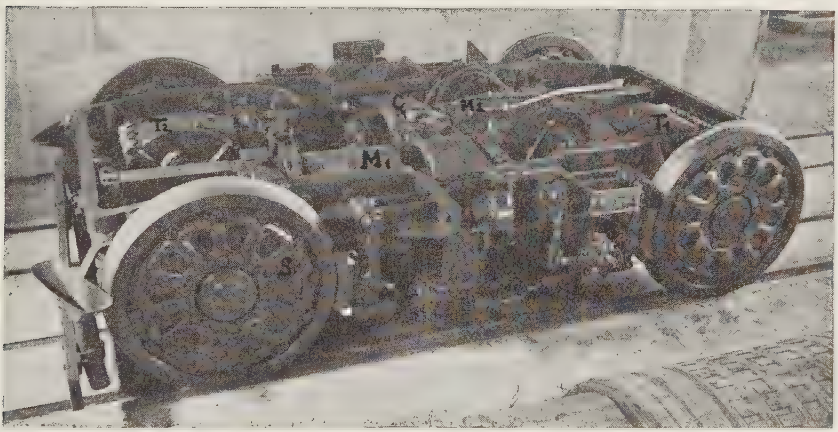


Photo TIBB (Brown Boveri).

Fig. 369. — 1948 bogie of the motor vehicles in the Turin (ATM) Tramway series, with SAGA type rubber mounted wheels, as in fig. 370.

M_1, M_2 = traction motors.

T_1, T_2 = corresponding transmissions from motor to axle.

C = pivot socket.

occasions, and on the last occasion in connection with the operating conditions; see pages including figs. 343 and 344. Four of these locomotives, Nos. 251-254, are now in service; fig. 366 shews locomotive No. 251 in service, during winter, with a passenger train, at the line terminal (Kandersteg), altitude 1200 m, cf. figs. 344 and 345. Fig. 367 is a diagram of the arrangement of the body suspension of these machines ([213]) and fig. 368 shews the suspension with oil shock absorbers, slides and axleboxes ([213]). A detailed description is given in the publications mentioned in notes ([140]) and ([212]).

([213]) See second publication of note ([140]), figs. 3 and 4.

Photo TIBB.

Fig. 370. — SAGA wheel dismantled; type for bogie in fig. 369; this wheel has the same rubber elements as fig. 319 and the same outside discs with ventilation holes as fig. 341.

So as to follow the same sequence as Chapter VI, we are shewing, in connection with figs. 251-254 on the one hand, and 255 on the other hand, in figs. 369 and 370 respectively, a driving bogie of one of the *tramway* vehicles with four axles of the Turin Transport system, Azienda Tranvie Municipale di Torino, ATM, and details of the SAGA flexible wheels of these cars. It will be seen that in this design, there are some fifty small rubber discs, of two different diameters, arranged on two concentric circles [214] (cf. figs. 319, 341 and 371).

Fig. 371 shews yet another use of the SAGA flexible wheels, intended for use on the 30 new railcars, Nos. 701 to 730, and fifteen trailers, Nos 301 to 315, 1949, high-capacity, of the Geneva Electric Tramways, CGTE.

We now come to the mechanisms with cardan hollow shafts and *laminated* plates, and shall deal first with the SAAS, Secheron Works, Geneva (which we shall call the Secheron III) for rail and tramway cars. This is a mechanism on the axle (i.e. a hollow shaft on the axle).

Fig. 372 shews the same mechanism as fig. 256 but in more detail and is more clearly described in the accompanying text. Reference may be made to fig. 257 and to the text on the same page [215]. Fig. 373 shews a bogie of one of the EBT-VHB, Swiss, railcars, type CFe $^4/_4$, series 141, dealt with at the top of the page including fig. 258. One of these cars was shewn in fig. 187.

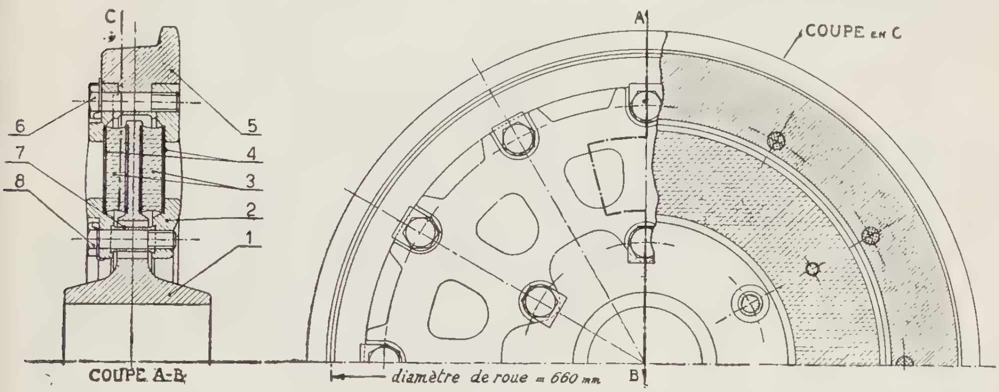
The same mechanism, of figs. 372 and 373 (bogie), is at present being manufactured for equipping eight driving bogies for the Swiss Federal Railways. These bogies are for the rail motor brake vans, Fe $^4/_4$, of the series 801-824 (formerly 18501-18524), shewn in figs.

[214] See *Ingegneria Ferroviaria*, Rome, Dec. 1948, pp. 733-738, « Progressi nella riduzione dei rumori e nella frenatura elettrica delle veture tranviarie », A. PATRASSI, 15 figs., of which fig. 13 shews the distribution of the small rubber discs of figs. 319 and 370. — Also compare *Economie et Technique des Transports* (bilingual, formerly *L'Allégement dans les Transports)*, Zurich, vol. 1940/1, pp. 9-14, 6 figs., « Gesichtspunkte für die Anwendung von Gummi als Federungselement für Strassenbahnen », W. PRASSE. — Still referring to *resilient wheels*, but for *railways* (Michelin pneumatic-tyred vehicles), see *Amis des Chemins de Fer*, Paris, Christmas number, 1948, pp. 121-124, 6 figs., « Le train sur pneus », P. L. GARNIER, referring to France, and with regard to Switzerland, *Bulletin des CFF*, Berne, No. 5, 1948, « Véhicules ferroviaires montés sur pneumatiques », R. GUIGNARD, reproduced in *Economie et Technique des Transports*, vol. 80/81, 1948, pp. 36-38.

[215] See *Bulletin Sécheron*, Geneva, No. 19F, 1947, already mentioned in note [116].

42 and 161. Of these eight bogies, four will be converted and improved (old bogies of the motor brake vans, 18501 series); the other four bogies will be *new* ones manufactured by the SWS Co., Schlieren-Zurich, already mentioned, but the drawings were not, up to the end of 1948, ready and nothing can at present be said regarding them.

Fig. 258 shews this Secheron IV (bilateral) arrangement diagrammatically, and figs. 259-261, its application to the new light cars of the Neuchatel Swiss Tramways [see note (154)]. Figs. 374 to 376 shew respectively the torsion bar with bilateral mechanism, pinion and brake drum, the traction motor with laminated mechanism and finally the bogie of the



Plan SAGA.

Fig. 371. — Flexible wheel developed for the new motor vehicles and trailers (series 701 and 301 respectively) of the Geneva Tramways, CGTE (Compagnie Générale des Tramways Electriques). (Cf. fig. 341.)

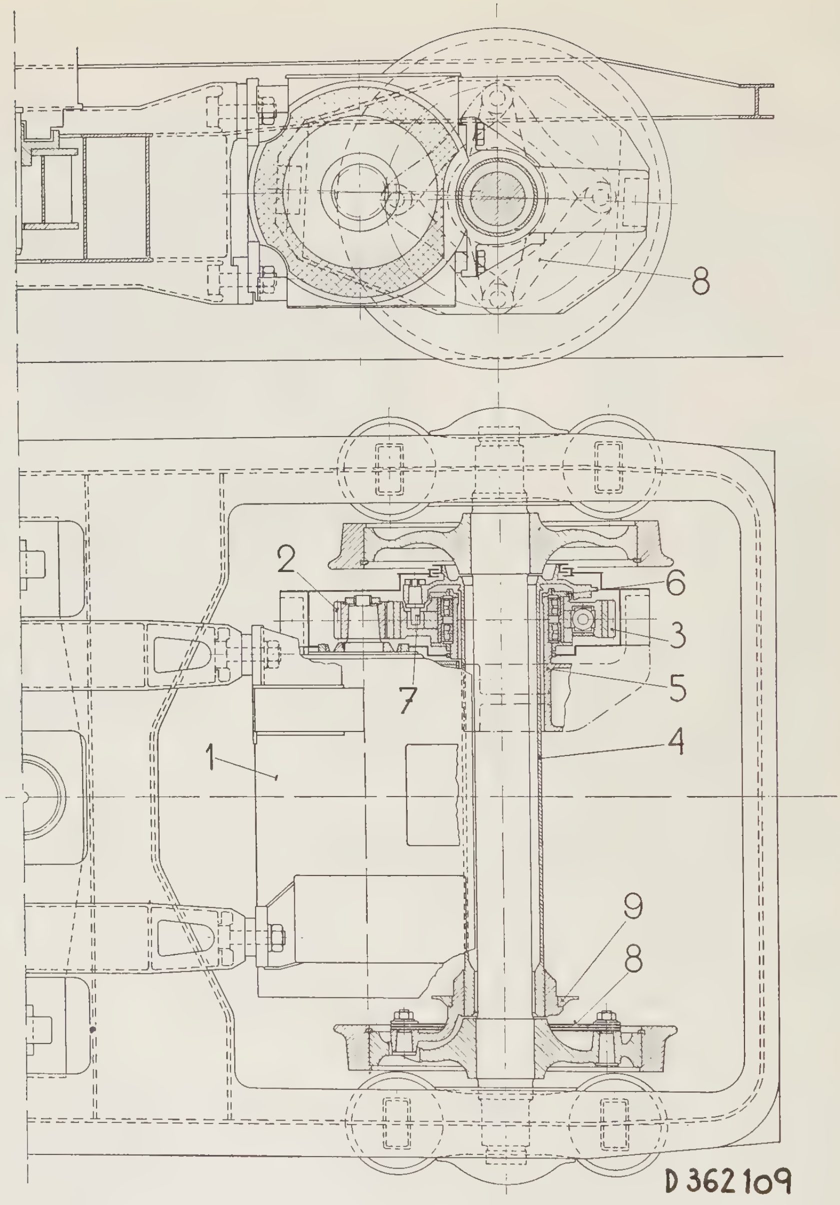
1. Boss.
2. Discs (interior and exterior) fixed rigidly to the tyre 5 by the bolts 6.
3. Rubber segments, divided into three 120° sections.
4. Metal armouring of the segments 3.
6. Fixing bolts (tyre side).
7. Spacing sleeves.
8. Fixing bolts (Boss side).

We now pass to *tramway* applications, in relation to figs. 258-261, with the mechanism which we shall call Secheron IV, in which the hollow shaft forms the motor armature, and the flexible transmission mechanism is located on the motor and not on the axle (see later description, of the Oerlikon arrangement, which apart from the cardan shaft is very similar).

new car No. 571 (217) of the Rotterdam Tramways RET, which was mentioned in the right-hand column of the page preceding Chapter VII. Comparing these three figures 374 to 376 with figs. 259-261, it will be seen that the mechanism has been simplified and improved, with, of course, some differences due to the operating conditions.

The Rotterdam bogie in fig. 376, of

(217) See *Bulletin Sécheron*, Geneva, No. 20F, 1948, p. 59.



Cliché Sécheron.

Fig. 372. — Diagram of Secheron III mechanism with hollow, cardan shaft and laminated coupling set in the axis of the axle as used on the bogie in fig. 373. This is of the same plan, meanwhile improved, as fig. 256.

1. Traction motor.
2. Pinion wheel to shaft of motor 1.
3. Geared rim.
4. Hollow shaft and cardans.
5. Stub shaft on hollow shaft.
6. Spherical bossing.
7. Driving pin.
8. Laminated coupling.
9. Contact ring for return of current to rail.

Secheron construction and fitted with SAB wheels as in fig. 255, can be described briefly as follows : there is no normal frame, the bogie comprising a central body, formed as a welded box, to which are linked four movable arms carrying at their ends the axle bearings. The traction motors are bolted on, the bolt holes being visible in fig. 375. This assembly bears on the axlebox through two longitudinal laminated springs, the ends of which engage in traps under the axleboxes.

The body of the car rests on the bogie through a double transverse spring which is accommodated in the central box. The pivot socket is fixed directly to the transverse spring, which is firmly secured at the centre. This method of supporting the body on the bogie is very simple, as it requires no swing bolster or rubbing blocks. Moreover, the same system has been used successfully on various other railcars built in Switzerland during recent years (cf. bogies described hereafter).

We now come to the laminated, cardan shaft, mechanism of the Oerlikon MFO Works, Zurich, which was mentioned at the beginning, under 3), and at the end of Chapter VI.

The drive shewn in figs. 377 to 379, belongs to the class of those in which the flexible element is arranged between the traction motor and the pinion, and therefore belongs to the same category as the new Brown Boveri disc mechanism (figs. 246, 247 and 252) and the Secheron IV just mentioned (figs. 374 and 375). It can be used either on railcars or on electric locomotives. For tramways, apart from recent uses in Europe of such mechanisms, based on a similar principle [218], a large number have been

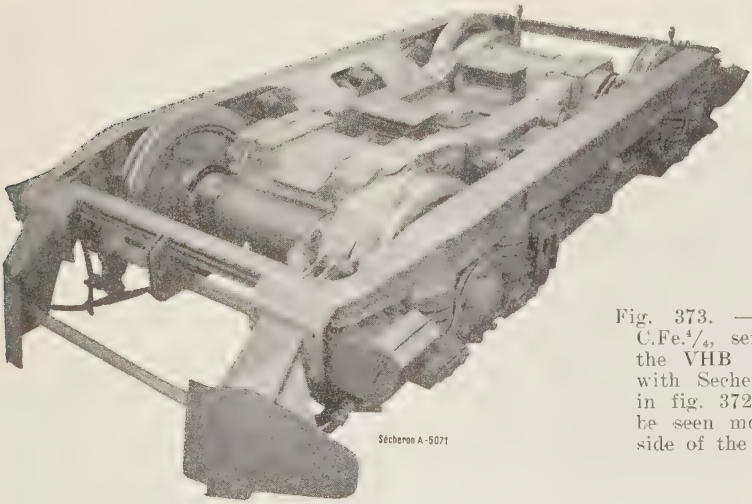


Fig. 373. — Bogie of a railcar C.Fe.$^4/_4$, series 141 (fig. 187) of the VHB (EBT) Railway, fitted with Secheron III mechanism as in fig. 372. The mechanism can be seen mounted on the interior side of the wheel disc.

Cliché Sécheron.

[218] For example, see fig. 197 of **Cde. indiv.**, Allenstown device on *4-motor bogie* built by J. G. Brill, Philadelphia, Pa., U.S.A. — See also *Amis des Chemins de Fer*, Paris, Jan./Feb., 1947, p. 10, fig. 5 (also note electro-magnetic brake).

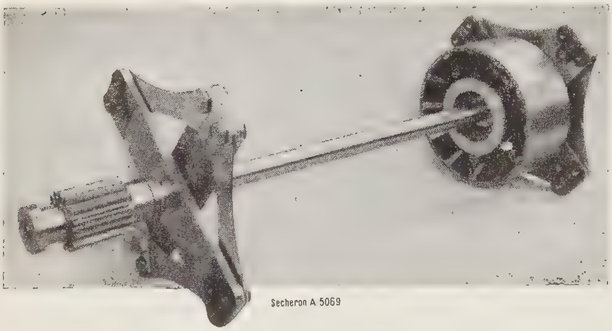


Fig. 374. — Torsion shaft (inside of hollow armature shaft) with bilateral Secheron IV mechanism and pinion, of the new motor vehicle No. 571, 1948, of the Rotterdam Tramways, RET. On the right is the brake drum.

Cliché Sécheron.

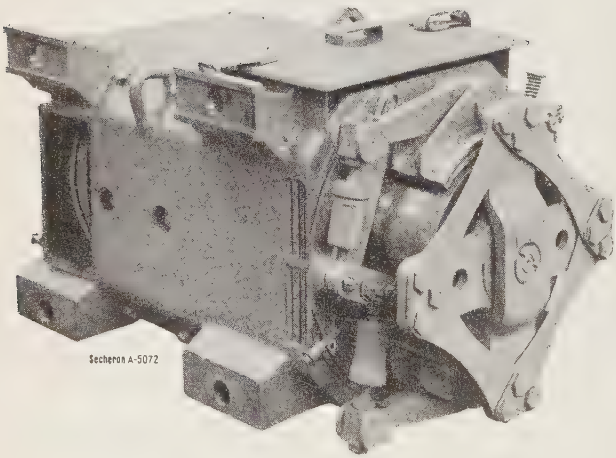


Fig. 375. — Traction motor of motor vehicle No. 571 of the Rotterdam Tramways, fitted with Secheron IV mechanism of fig. 374. In the foreground can be seen the mechanism at the opposite end to the pinion, with the brake drum. On the left are the four bolt holes for fixing the motor to the bogie frame. (Cf. fig. 379.)

Cliché Sécheron.

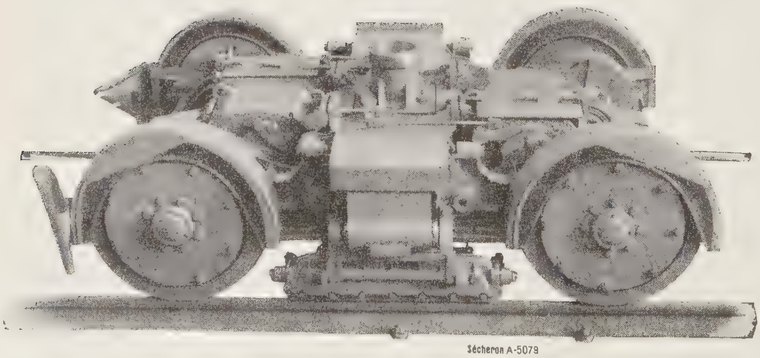


Fig. 376. — Secheron type driving bogie of motor vehicle No. 571, Rotterdam Tramways, fitted with mechanism in fig. 374 and motor in fig. 375.

Cliché Sécheron.

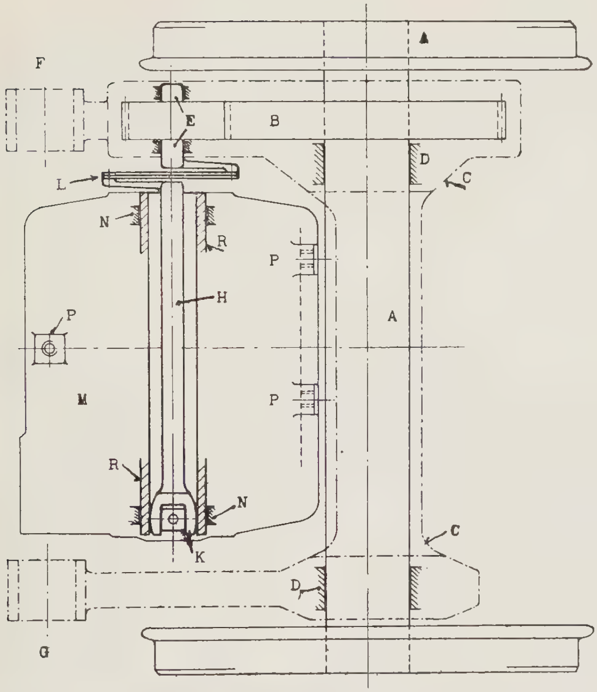


Fig. 377. — Diagram shewing arrangement of driving mechanism with cardan and laminated coupling Oerlikon type. See figs. 378 to 381. For key to lettering see text.

Plan Oerlikon.

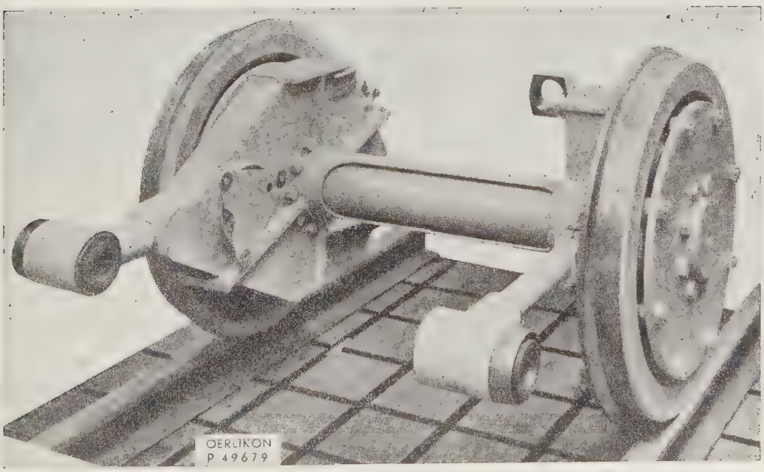


Fig. 378. — Axle assembly with housing and support arms, bogie of fig. 380, Zurich Tramways, St.St.Z., as in fig. 377. SAB wheels as in fig. 255.

Photo Oerlikon.

in use, particularly in the U.S.A., for about 15 years.

This class of drive is also characterised by the fact that the traction motor M (see fig. 377) is solid with the bogie frame, the vertical play of the driving axle A being taken up by a flexible coupling which allows movement in the

requisite directions. On the Oerlikon mechanism (which is unilateral, whilst the Secheron IV and the Brown Boveri arrangement mentioned above are bilateral, on both sides of the motor), the spindle R of the motor (hollow armature shaft) is mounted on a cardan joint K of special construction, inside the armature itself alongside the commutator. The end of the torsion bar H, emerging

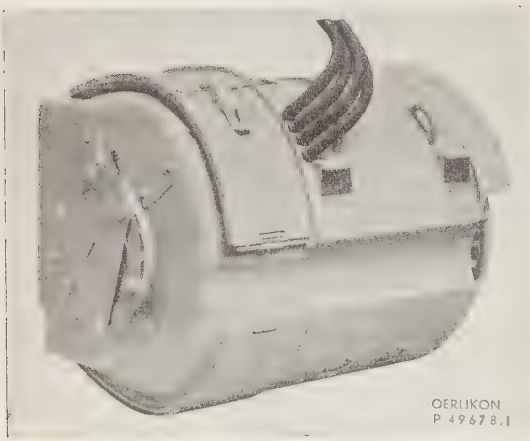


Photo Oerlikon.

Fig. 379. — Oerlikon traction motor with cardan in hollow armature shaft and Oerlikon laminated mechanism (at opposite end to commutator) as in figs. 377, 378 and 380. (Cf. fig. 375.)

from the motor, can be moved freely in a vertical direction without any recoil effect. The case C for the gears B, of either cast steel or fabricated from plate, is carried at one end by rollers on the driving axle (bearings D) and is suspended at the other end from the bogie frame (three mounting points P); this allows the casing assembly a certain degree of rotation (perpendicular to a vertical plane through the longitudinal centre line of the vehicle) around the axis of suspension FG, the position of which can vary slightly, the ends of the supporting arms shewn in fig. 378, being fitted with a type of rubber silent-bloc. The large gear wheel is keyed directly to the axle. The pinion rotates in two rollers E, which are solid with the case. From figs. 377, 378 and 380, the arrangement of the casing assembly can easily be seen. By an exact centring of the pinion a positive fixed gearing is obtained, which is further improved by helicoidal gears. The union of the motor torsion bar H and the pinion shaft is effected by a flexible, laminated, L-shaped coupling, made up of thin steel plates which are fixed at both ends to triangular-shaped hubs, rigidly fixed to the motor and pinion shafts respectively. This arrangement is clearly shewn in the foreground of fig. 379. The combination of cardan joints (working with practically no friction) and steel laminations avoids any supplementary restriction (which is always difficult to overcome) and allows the design to follow the most favourable proportions. The armature, at the same time the hollow shaft, is carried in the bearings N, which form part of the field, that is, the motor body fixed to the bogie frame.

We may also note that the Brown Boveri mechanism, figs. 239 and 246, and the Secheron, figs. 258 and 259, both bilateral, contain either a cardan joint or a group of components similar to a cardan. A particular advantage of this Oerlikon mechanism is its compactness, since the articulation (the cardan joint K of fig. 377) is located inside the motor and therefore demands no additional space. This cardan joint inside the motor is lubricated, as are the rollers, by grease, which it is only necessary to examine and replace if required at normal

overhaul periods. The cardan is very easily dismantled. The case-hardened parts, even after several years, should suffer practically no wear since movement is kept to a minimum.

The L-shaped coupling laminations (shewn in figs. 377 and 379) located outside the motor require no lubrication. They are quite accessible and the elements can easily be replaced. On removing the laminations, the traction motor may be separated mechanically from the driving axle. This applies also in the case of disc mechanism (see fig. 252). The removal and replacement of a traction motor can therefore be effected quickly. The Oerlikon cardan and laminated drive, before being put into service, was given prolonged and severe bench tests. It has therefore given good service in two years of normal operation with cars Nos. 1376 to 1380 of the Zurich Tramways, St.St.Z. Figs. 251 and 380 should be compared; these shew the two modern bogies of this large undertaking, which it may be mentioned in passing is in certain respects the second largest in Switzerland, ranking next to the Swiss Federal Railways.

This Oerlikon drive can be built for any higher rating, with practically no limit. Its compactness is particularly convenient for the use of bogies with inside bearings, as are preferred for tramways, particularly those of narrow gauge. It has been used on several systems, i.e. (1) the Zurich Tramways, cars Nos. 1376 to 1395, 20 in number, some still under construction (40 bogies as fig. 380); (2) also on the Zurich St.St.Z.,

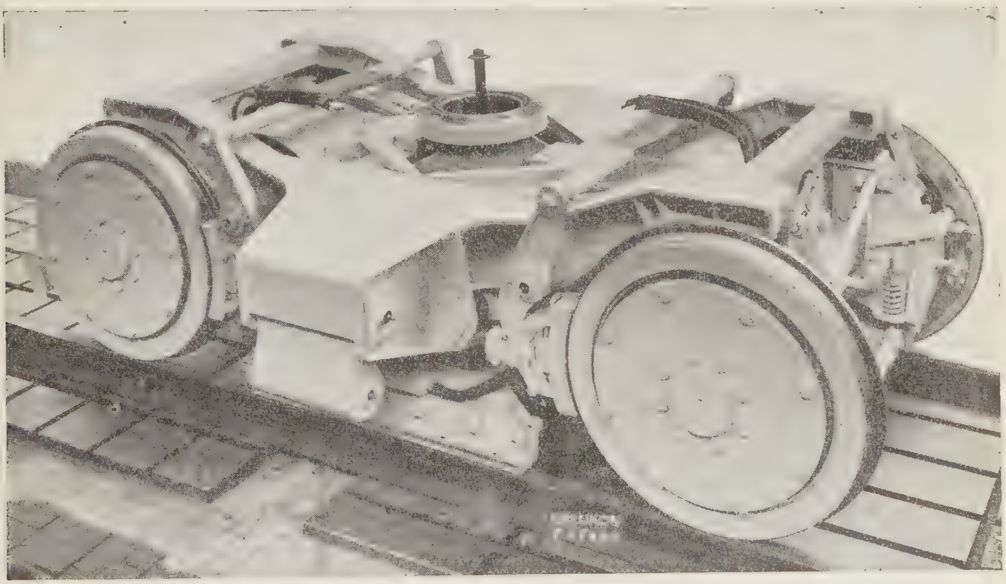


Photo Oerlikon.

Fig. 380. — Driving bogie, as in figs. 378 and 379, of the Zurich Tramways, St.St.-Z., 1948 type, fitted to motor vehicles 1376 to 1395. The third point of suspension of the motor (left) is visible immediately to the left on the pivot. Cf. figs. 250-253.

this bogie is to be used on the two new experimental light cars Nos. 1651 and 1652; (3) on the Forchbahn A.G. (Zürich-Egg-Esslingen) on cars Nos. 9 and 10; (4) on the Sernftalbahn A. G. (Schwanden-Elm; Glaris Canton of Switzerland) on three cars Nos. 5-7. All these date from 1946 to 1949, and all the above lines are operated by the Zurich St.St.Z. ([218b]).

A comparison of these various mechanisms (discs or laminations) from the operating and behaviour points of view shews that there is practically no difference between them as regards wear and maintenance, wear is in any case very small or even non-existent in all these mechanisms.

The bogies of the two figures, 380 and 381 (Swiss patent 253388), built by the SWS works, Schlieren-Zurich, already mentioned, can be briefly described as follows ([219]) :

Despite the different outward appearance (adapted to the different operating conditions of the respective lines) the principle of the construction of these two figures is the same. In developing the construction a simple structure has been sought giving the maximum of accessibility and a minimum cost of maintenance in service.

The unit formed by the bogie frame and the traction motors bolted to it (the bolt holes being shewn in fig. 379) is supported on rubber springs on the roller bearing boxes and is thus fully suspended. Apart from this, the wheels of the tramway bogie in fig. 380 are SAB resilient type (cf. 251, 255, 376 and 378). The motors can easily be removed from the bogie, either from above (without lifting the body) or from below. The axles, with the axleboxes and gear case (fig. 378) are carried by their supporting arms at the central part of the bogie by means of spherical joints. A transverse guiding bar mounted on silent-blocs, as are the supporting arms, joins the motor and frame to the axle thrust bearings, which allows a perfect alignment of these items with the axle. The cradle arrangement of earlier constructions, resting externally on longitudinal springs, has been replaced by a transverse spring which has already been used frequently with success. Considerable simplification as well as a reduction in weight has thus been obtained.

The body of the vehicle is carried on the bogies by means of a central supporting pivot (visible in fig. 380) which transmits the load and horizontal forces to the bogies and transverse spring respectively. As a result of this arrangement, it has been possible to eliminate the lateral body supports, which required inspection and maintenance. For this and other reasons, a direct bearing on a single pivot may be considered an ideal solution. Re-greasing of the pivot is carried out only at periodical overhauls.

The height of the body floor above rail level can, with this type of bogie, be

([218b]) With reference to the Forchbahn (Zurich) railcars, see *Verkehr und Technik*, Berlin-Bielefeld-Detmold, May, 1949, pp. 85-87 (fig. 1-5), « Moderne Fahrzeuge fur Lokalbahnen », Ad. M. HUG. — Sernftalbahn (Glaris) railcars were described for the first time in the *Neue Zurcher Zeitung*, *NZZ*, Beiblatt *Technik*, No. 1445, 13-7-1949, 1 p., 3 fig., A. BÄCHTIGER. — See fig. 381 following.

([219]) For comparison of different types of tramway bogies in Switzerland, we may quote the Dornier Works, now « Flug- und Fahrzeuge A.G. », of Altenrhein (Switzerland), bogie used on the 15 high-capacity trailers of the Basle « Basler Verkehrsbetriebe » BVB, a type of bogie quite different in conception from those described, and of light construction. See *Der Oeffentliche Verkehr*, Berne, Dec. 1948, p. 9.

raised or lowered as required, within the limits of the hangers provided; there is no necessity to change the height of the pivot by keying up, nor to adopt any other means.

It will be seen that the bogie in fig. 381 carries on the pivot the transverse springs with the hangers for securing the body, whilst the bogie in fig. 380 has the transverse spring inside the central assembly, as described in connection with fig. 376.

The brake shoes and rigging have been arranged in the same manner as previously (SWS construction) without alteration. The blocks can be used until they are practically worn through, thanks to an automatic repelling device for the shoes which requires no additional mechanical assistance.

The electro-magnetic rail brakes, placed between the bogie axles are flexibly fixed to the non-suspended part of the bogie (apart, of course, from the resilience of the SAB wheels, fig. 55.)

The supporting frames for the electro-magnetic brakes, to which are fixed the sand pipes, are in three parts to allow for easy dismantling, from below, of the motors. Finally, the air-cooling arrange-

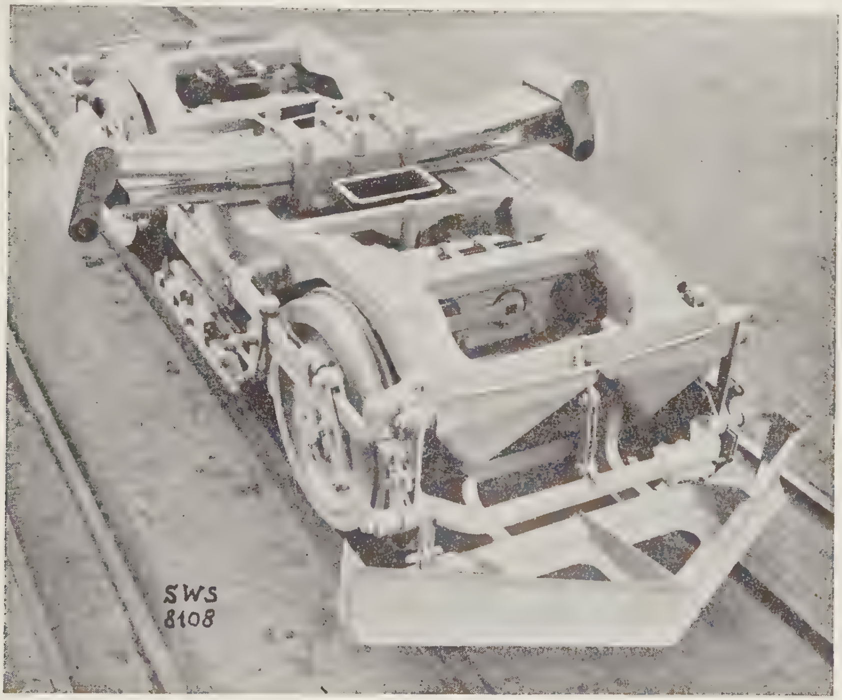


Photo SWS-Schlieren.

Fig. 381. — Bogie of the railcars of the two local railways (Forchbahn A. G., Nos. 9 and 10, and the Sernftalbahn, Glaris, Nos. 5 to 7) operated by the Zurich Tramways St.St.Z. This bogie is fitted with mechanism as in figs. 377 to 379. (Cf. fig. 253.)

ment for the motors is very simple; air enters the hollow central part of the bogie frame where it is filtered through a succession of sieves. This air is fed to the traction motor from the hollow frame and the accumulated dust and grit is removed at periodical inspections.

We thus come to the end of our remarks on Chapter VI. As there is nothing to add with regard to Chapter VII, and all matters relating to individual drive and resilient wheels, bogies, etc., of tramways have just been covered, we may now conclude with a description of two arrangements which refer to Chapter III, item 3), the British gear wheels with rubber mountings mentioned in note (202).

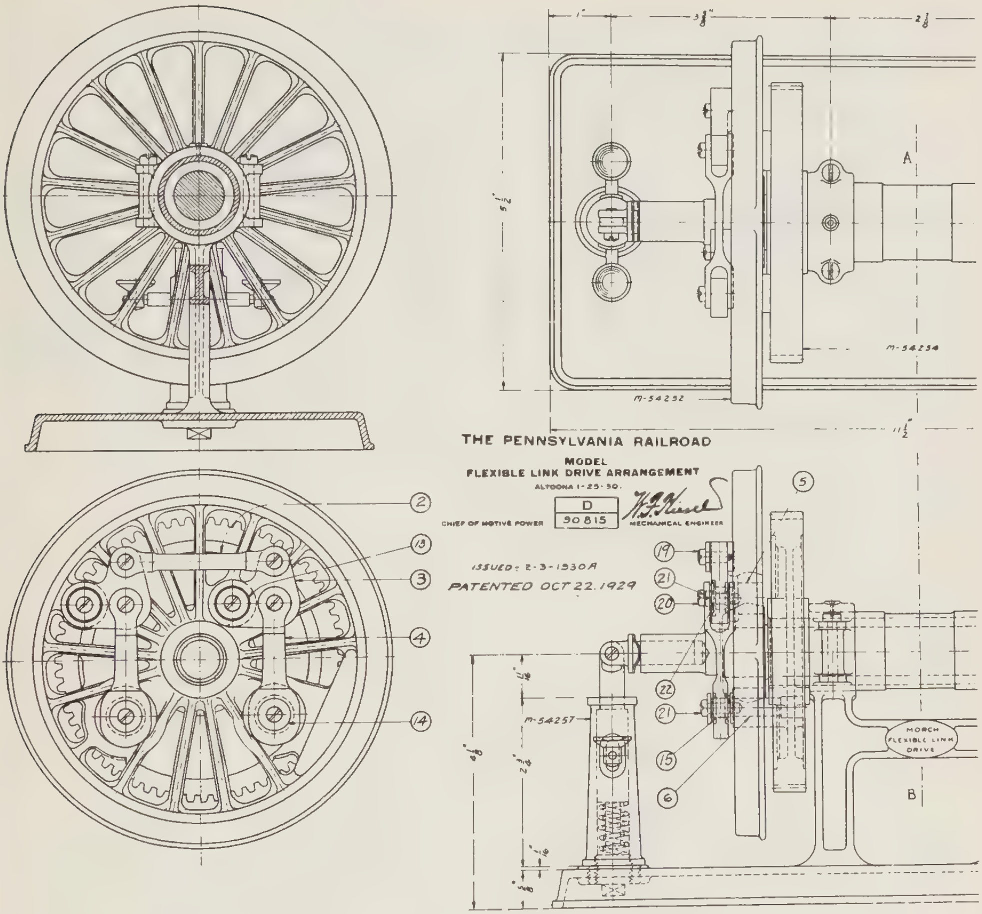
1) Mention was made, on the page containing fig. 293 (at the end of the remarks relating to Chapter III), of the *American* « Morch » mechanism, which had not been noted on the page following fig. 31, as nothing had then been reported on it.

This « Morch » mechanism of the Pennsylvania RR was used on 01 class locomotive type 2-B_0-2, No. 7850 (fig. 293, cf. fig. 65 of **Cde. indiv.**, and fig. 16) but only from 1930 to 1944; it can be seen in fig. 378, and can be described as follows :

Comparing the elevation (bottom left) of fig. 382 with figs. 120 to 122 of **Cde. indiv.** (Skoda mechanism of the Czech. locomotives, series E.466 CSD, 1926) and fig. 10 (Ganz mechanism of Italian locomotives Gr.E.334, FS, 1902) we see the great similarity of these two mechanisms (and the principle of the operation) to the 1929 Morch mechanism. The two vertical rods 4, and the horizontal link 2 of fig. 382, are identical with those designated by CD and BB respectively, in the Skoda mechanism (fig. 120 of **Cde. indiv.**) whilst the two oblique levers AB of the Skoda are replaced by the triangular levers 3, similar to those designated H_1 and H_2 (fig. 10 of **Cde. indiv.**) of the Ganz mechanism. Whilst referring to the descriptions of these two fairly old mechanisms (see pp. 9 and 58 of **Cde. indiv.**), we may point out that the two pivots 14, of the rods 4, pass the driving wheel through the holes 6 and are fixed to the body of the gear wheel. Furthermore, the two pivots 20-21 of the same rods 4 are fixed to the angle of the triangular levers 3, which by their main pivots 13 are secured at 5 to the driving wheel centre. Finally, the opposite angles of the two triangular levers 3 are linked by means of the bolt 19 to the conjugated rod 2. The method of operation is consequently clear. A certain similarity to the Buchli (Brown Boveri) mechanism of figs. 38, 54 and 67 of **Cde. indiv.** is also seen, the conjugation of the two main rods being by means of the geared segments which engage them.

2) We will now describe a mechanism very similar to that of Als-Thom — France (figs. 285, 286 and 291), but having no silent-blocs in the joints, developed in Britain by the English Electric Company, with a view to its use on high-speed railcars, and by H. I. ANDREWS (220).

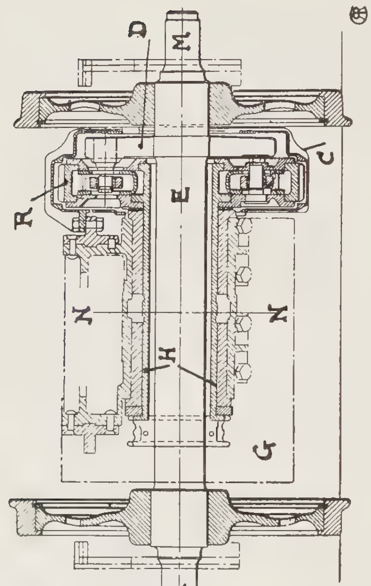
(220) See *The Engineer*, London, 23 and 30 April and 7 May, 1948 (pp. 409-411, 434-435 and 457-458), 11 figs., « The mobile locomotive testing plant of the LMS Railway », H. I ANDREWS. The generator car, fig. 6, is shewn and described, p. 435, and the mechanism (figs. 7, 8 and 11), pp. 457-458. — Meeting of the Institution of Mechanical Engineers, London, 16-4-1948. — See also *The Locomotive*, London, Oct. 1947, and *Glasers Annalen*. Berlin, Feb. 1948, p. 30, « Lokomotivmessung der Englischen London, Midland und Schottischen Bahn ».



PRR plan.

Fig. 382. — Rod and lever mechanism, designated « Morch flexible link drive » of the Pennsylvania RR, used from 1930 (?) to 1944 on two driving axles of the locomotive in fig. 293. Unilateral drive and gears; otherwise, the sectioned portion at the right of the plan is symmetrical, on the axis AB, with the part shown. The parts above and on the right show the mechanism mounted on the axle on a test bed (special supports for the axle shown), whilst the bottom, left, illustration shows an elevation of the driving wheel only, with the transmission mechanism and the gear wheel (also shown in the two right-hand illustrations).

2 = Link between the two transmission units.
3 = Triangular levers for absorbing play during movement.
4 = Driving rods (cf. figs. 17 and 20, also 38, 52, 66 and 67 of **Cde. indiv.**).
5 and 13 = Pivots fixed to driving wheel.
6 and 14 = Pivots fixed to the gear wheel.
15 and 22 = Spherical bearings.
19 to 21 = Fixing bolts.



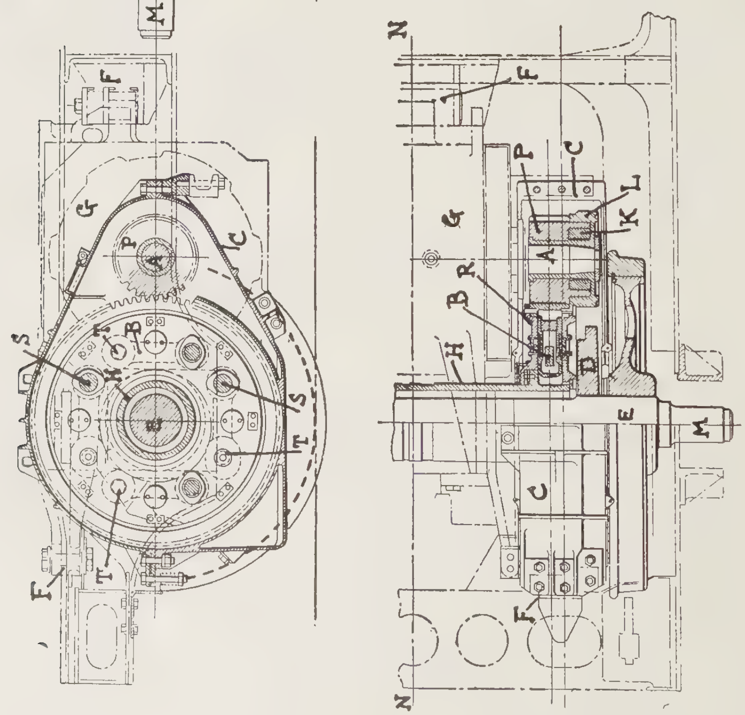
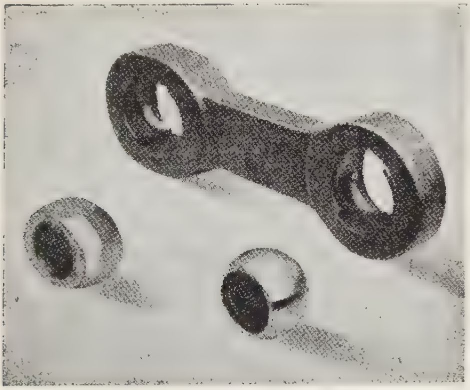


Fig. 383. — Rod mechanism « Andrews-English Electric », in elevation and sections of the driving axle — generator assembly used on the generator coach (for average speeds) of the LMS (British Railways) dynamometer set. The generators are mounted in the bogie frames in the same manner as traction motors in the plane of the axle centre line. For explanation of letters, see text.

From *The Engineer.*



From *The Engineer.*

Fig. 384. — A rod B of the fig. 383 mechanism, with the spherical sleeve bearings fitted on the inside with needle bearings.

It is shewn in figs. 383 and 384 and is known as the Andrews-English Electric.

This is a highly specialised application for a dynamometer car set for testing steam locomotives by the LMS (British Railways). One of the cars of this set produces, for purposes of testing and controlling locomotives, the electric current necessary for measuring tractive effort, the resistance to movement being regulated as desired by the excitation of the generators. The four « traction motors » of this car are, in fact, the *generators* operated by the movement of the set, which is hauled by the locomotive under test.

As will be seen from figs. 383 and 384, the mechanism comprises (in a similar manner to fig. 286, but *without* the central connecting arm around the hollow shaft) four rods B, the two ends of which are connected at S to the driving wheel (that is, to a disc D keyed to the axle E, mechanism and gears being unilateral) and at T to the gear wheel R. The pinion P, the rim of which is given flexibility by means of springs (visible in the centre of fig. 385) is mounted on the shaft A of the generator G in the same housing C as the gear wheel R, these two components being keyed to the hollow shaft H. The journals for the roller bearing boxes are marked M; the vertical plan along the bogie centre line is marked N-S. The buckle spring of the pinion (centre of fig. 385) is marked K and the retaining cap of the spring (left of fig. 385) by L.

The driving rods (fig. 384) have at the ends, instead of the silent-blocs shewn in figs. 285 and 286 (cf. fig. 27) spherical pivots with needle bearings, visible at the bottom of fig. 384.

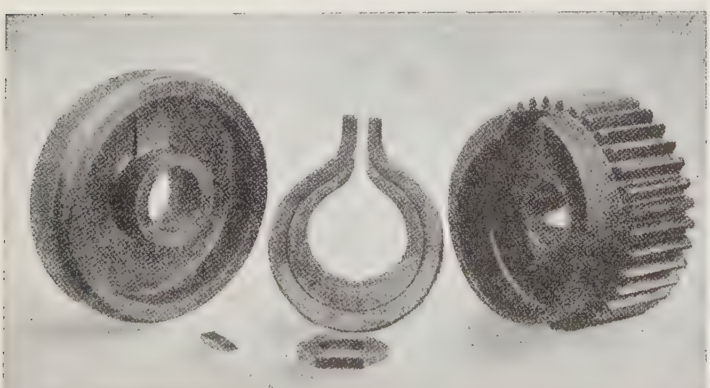
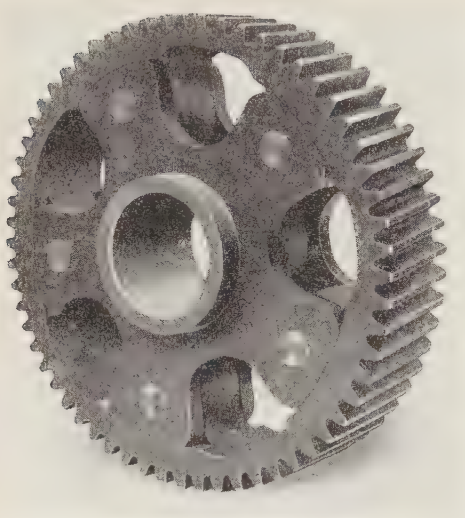


Fig. 385. — Pinion P of fig. 383 mechanism. Right, the pinion P; centre, the buckle spring K and left, the retaining cap L of the spring K in the pinion.

From *The Engineer.*



Cliché Metrovick 31963.

Fig. 386. — Resilient gear wheel with rubber silent-blocs, modern type for tramways. Cf. fig. 388 for make-up.

It is difficult to form an idea of the practical value in operation of this mechanism for use on fast motor coaches. It is certainly very complicated and contains a large number of parts; in addition, it has only been in use for one year (1948) and is only used occasionally (dynamometer car set); it is clear that various other mechanisms dealt with in this work are simpler and less costly in operation. It is obvious that as it forms part of a dynamometer car set, it is very carefully maintained.

Finally, we can only mention another mechanism similar to that in figs. 285 and 291, *which has never been fitted* and has therefore not passed the design stage, proposed by the Allis-Chalmers Manufacturing Co., Milwaukee, Wis., U.S.A., for a 2-D_0-D_0-2, 4 000 HP, gas-turbine locomotive [221]. The four hollow shafts

Fig. 387. — Resilient gear wheel with silent-bloc inserts, type for railcars. The pinion is solid steel. Cf. fig. 388 for interior arrangement.

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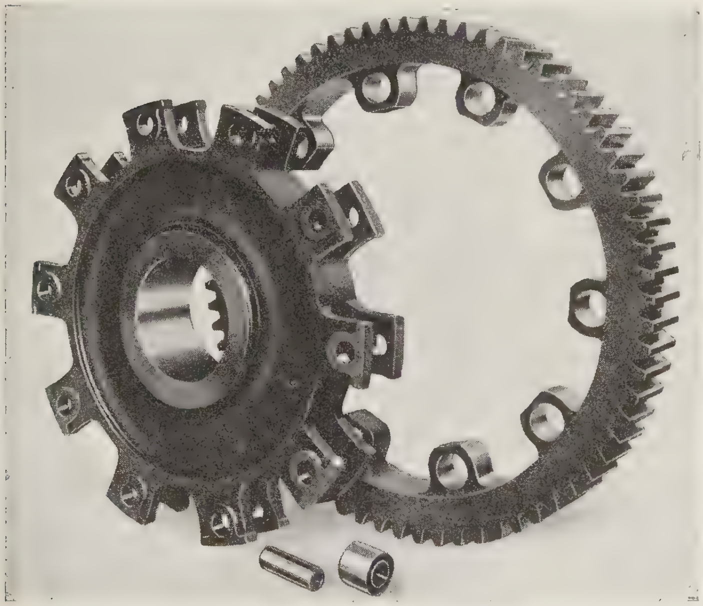


Fig. 388. — Resilient gear wheel, locomotive type, dismantled. The cylinder at the bottom centre is placed in the holes in the geared rim; it is composed of two concentric metal tubes, with rubber insert (vulcanised). The pivot pin, bottom left, passes through the cylinder and is fixed in the holes of the gear wheel centre (left).

Cliché Metrovick 83858.

of the driving axles are fitted in the centre with a worm reduction gear and driven by a single electric traction motor for each bogie, placed under the driver's cab. The individual drive is therefore relative, as in other mechanisms mentioned (figs. 23, 95, 358, etc.). The driving pins (bilateral) of the driving axles are fitted with silent-blocs [fig. 5 of publication in note (221)]. This proposed prototype locomotive should weigh about 255 tons, have an operating speed of 160 km/h. (100 m.p.h.) and a tractive effort of from 23 000 to 55 000 kg (50 700 to 121 250 lbs).

3) To conclude this work, as mentioned above, we shall now refer to the British *flexible gears* with rubber inserts (already mentioned at the bottom of the page with fig. 341, and relating therefore mainly to Chap. IV), used in numerous cases on motor vehicles (electrically driven).

These are of three different types, i.e.:

a) tramway type (see fig. 386);

b) railcar type (see fig. 387);

c) locomotive type (see fig. 388).

More than 1 500 type *a*) have been used, particularly in Great Britain, since 1931. The most frequent applications have been in the conditions indicated in the following table, items 1 and 2.

Of type *b*) more than 750 resilient gear wheels have been supplied for railcars or railcar sets, particularly in 1948 for the South African Railways and Harbours and the Netherlands Railways. These are shewn under items 3 and 4 of the table.

(221) See *Railway Mechanical Engineer*, New York, Oct., 1948, 5 p., 5 figs., « Gas turbine power » (4 000 HP gas turbine locomotive), W. GIGER. (Extract from proceedings of a meeting, held on 7th. Sept., 1948, at Portland, Oregon, of the American Society of Mechanical Engineers, Power Division). An exception has been made in this, because of the standing of the Author, to the rule followed in this work of not dealing with projected designs not so far applied.

Applications	Item	Reduction ratio :	Modulus of teeth	Hourly rating of motor for each axle
Type *a*) tramway (fig. 386)	1 2	13/71 12/75	6.35 7.4	35 HP 60 »
Type *b*) railcars (fig. 387)	3 4	18/64 22/57	12 10	330 » 253 »
Type *c*) locomotives (fig. 388)	5	23/71	13.4	415 »

Finally, more than 150 type *c*) gear wheels have been put into service since 1947 on the South African Railways, as indicated under item 5.

The first rubbered gears for heavy traction [of three types, manufactured by Metropolitan Vickers Electrical Co., Manchester, see note (202)] were built in 1939, but the war delayed their fitting. A certain number of locomotives or electric railcars with gears similar to those of types *b*) and *c*) are under construction for Great Britain, Eire, South Africa, South America and Poland.

Finally, it may be mentioned that the arrangement shewn in fig. 340, and designated « resilient gear wheel » was designed and introduced by « Le Matériel Electrique S-W », of Paris, to whose order it was manufactured by Etablissements DSN, of Grenoble. Its conception dates from 1937 and without the war, the teething troubles mentioned at the right of fig. 342 would no doubt have been overcome in a very short time.

[625 .13]

The Channel Tunnel,

by George Ellson, C. B. E., M. I. C. E.,

Consulting Engineer to the Channel Tunnel Co.

During the period, which has passed since the inception of the idea of the Channel Tunnel, it has received the attention of the leading engineers, geologists and traffic experts of the day on both sides of the Channel and a lively interest has always been taken in it by the Governments of both Great Britain and France.

The practical possibility of the execution of the work is based on the fact that the chalk strata of the adjacent countries on either side of the Channel have precisely similar characteristics in the vicinity of the two selected outlets and that between those two points the bed of the channel consists of a layer of chalk of suitable texture and thickness to accommodate the tunnel in the same way that the London Clay bed beneath the metropolis has been used for the Tube system.

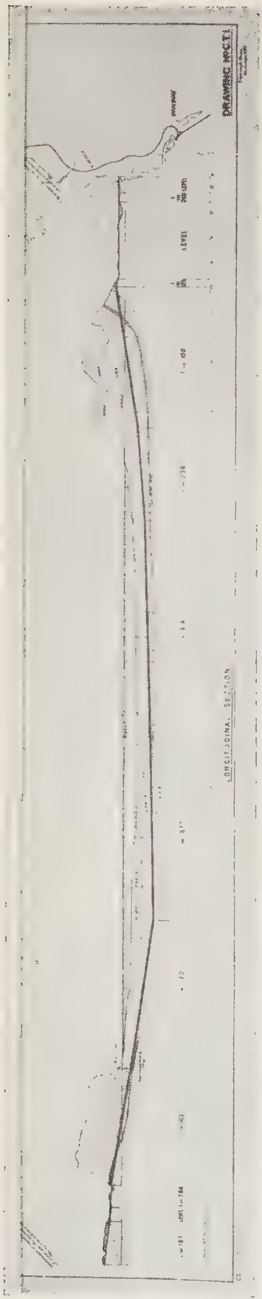
This chalk is the Lower Grey Chalk which is an impervious stratum, greyish in colour, containing no flints and is an excellent material in which to work, lending itself to easy excavation by tunnel boring machinery and being practically self-supporting in the process. In fact, tunnels bored in 1883/4 above sea level on the English coast in similar chalk still retain their contour although entirely unlined and, further, those bored under the channel about the same time, when entered many years later were also found intact.

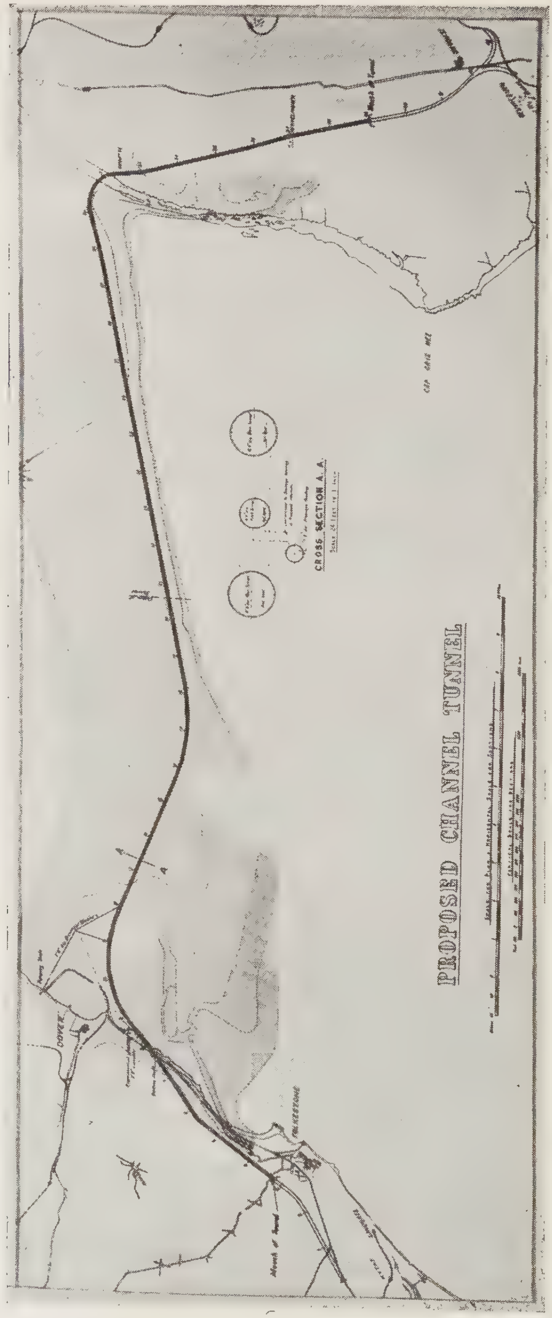
Geological investigations having established the boundaries of the bed of Lower Grey Chalk, the location of the Channel Tunnel Railway in that stratum has been decided so that the entire length of the submarine tunnel shall lie therein both in regard to alignment and level.

Route and description of the tunnels.

The new Channel Tunnel Railway will leave the existing main line from London to Dover at a point three miles on the London side of Folkestone, and it will proceed over open country to the foot of the hills just east of Folkestone, where each line will pass into a separate tunnel constructed in the lower chalk stratum which outcrops at this point. These tunnels will proceed on a falling gradient parallel to the coast until they reach a point near Dover, where they will turn right and pass under the sea on a series of easy gradients until they commence to rise again as they approach the French coast near Sangatte. On reaching the surface five miles beyond Sangatte the tunnels will merge into a double line of railway which passes through open country until it joints the main Calais-Paris railway near Boulogne.

The total length of the Channel Tunnel Railway will be 44 miles, divided as follows : open railway on the English side, 3 miles; the actual tunnels, 36 miles,





By courtesy of the British Railways.

of which 24 will be under the sea and 5 miles in the open country on the French side. In the first case, it is proposed to make a pilot tunnel 12 ft. in dia., the object of which is partly to confirm the opinions of geologists in their view that the lower chalk stratum is continuous throughout, but chiefly to ascertain whether or not there are any serious faults or fissures.

The diameter of the main tunnels will be approximately 17 ft. as compared with the 18 ft. 6 in. allowed for in the original scheme. They will be lined with ferro-concrete segments. In addition to the main tunnels, however, there will be a drainage tunnel from 7 to 10 ft. in dia. from a point east of Dover to Sangatte, about 20 miles. Although the scheme is called the Channel Tunnel scheme there will really be three tunnels, namely, two single-line train tunnels and one drainage tunnel. The depth of the main tunnels under the bed of the sea varies from 95 ft. to 170 ft., and the maximum depth of water on the route of the tunnels is 165 ft.

Practicability of the tunnels.

As already stated, the tunnels will be cut throughout their whole length in the lower chalk formation which runs from coast to coast. This stratum, which has a mean thickness of about 150 ft., is in the shape of a saucer, and is admirably suited for the purpose proposed. The main, and practically the only, difficulty, is to know whether it is free from faults of sufficient dimensions to prevent or impede seriously the construction of the tunnels.

To test this the following explorations have been carried out : In 1874 the French company obtained a concession from the French Government to construct a shaft near Sangatte and to drive a gallery under the sea for a distance of 1 1/3 mile. The work was duly carried out. In 1881 the South Eastern Railway Company obtained an Act giving it power « to make experimental borings and to carry out certain other works in connection with a tunnel ». A shaft 160 ft. deep was also sunk near the Shakespeare Cliff and a tunnel 7 ft. in dia. was formed for 2 015 yd. under the sea.

In 1921, a tunnel 12 ft. in dia. was excavated, by a tunnel boring machine, near the Martello Tunnel where the lower chalk stratum outcrops. Other headings have been made in the same area. All these works show that the lower chalk is easily manipulated and that the tunnels retain their shape although unlined. No serious difficulties were experienced from infiltration of water.

In 1875-1876 a large number of shallow borings, over 7 600 in fact, were taken from the soil under the sea between Dover and Sangatte, and no fewer than 3 267 of these penetrated into the lower chalk, in which the proposed tunnels will be constructed. Nevertheless, it cannot be stated definitely that the scheme will be free from trouble until the pilot tunnel is completed throughout.

The estimated cost (*).

In the early part of this century the cost of making a Channel Tunnel between England and France was estimated at about 16 000 000 £. In the report of the Channel Tunnel Committee of 1929,

(*) Calculations made before the devaluation of the £.

the estimated cost of the pilot tunnel is shown at 5 600 000 £. and of the main tunnels and their equipment, together with the drainage tunnel, at 25 300 000 £. total of 30 900 000 £.

Experience has shown that substantial economies can be made as compared with the scheme of 1929 and the present day cost of the work is estimated at between 50 and 60 million pounds.

If the higher figure be taken and to it is added 6 000 000 £. to cover payment of interest on capital during construction, a total cost of 66 000 000 £. is arrived at.

These estimates do not cover the cost of the exchange station or marshalling yards at either end or of the necessary land. The pilot tunnel will cost about 10 000 000 £. and will take from five to six years to build. The annual cost, therefore, for the first five of six years, after allowing for interest on capital during that period, should not exceed 2 000 000 £. The estimated time which will be taken to complete the whole tunnel is about eight years.

[625 .173 (42)]

The Southern Region track laying machine,

by J. D. West, A.M.I.C.E., A.M.I.Struc.E. (Associate Fellow.)

(Read to Croydon Section, 23rd February, 1949.)

(From the *Journal and Report of Proceedings, The Permanent Way Institution, August, 1949.)*

In presenting my paper on the Southern Region Mechanical track relayer and briefly summarising the reasons for its inception, perhaps a few words on pre-assembled track relaying by crane, the forerunner of this machine, would not be out of place.

The set up for crane relaying as used on the Southern Region, comprises a modern general purpose steam crane of 10 tons capacity or thereabouts, speedy in all its movements and operated in conjunction with a lifting bale of special design. Two tracks are required for relaying by this method and good headroom and side clearances are essential.

Crane relaying came to the London East Division in 1944 and soon there was no doubt that it had come to stay. However, it became increasingly apparent that much of the London East Division lacked adequate headroom and side clearances to provide the freedom of movement essential for crane working and thereby a considerable track mileage lay outside the scope of this method of relaying.

Bridges, retaining walls, tunnels—there are approximately 15 miles of double track tunnels on the division—are effective barriers to crane working. I am referring of course to the out of gauge parts of the crane when in operation—the long jib, the tail weight and the deep bale with its central suspension.

Near London many miles of tracks radiating from the terminal stations are carried on viaducts, the parapets of which once again prohibit crane working. Also the adjacent tracks often complicate the arranging of possessions.

And so, « Pre-assembly » having established itself on the division, it became more and more evident that mechanisation had to be carried into tunnels and such places by some means that would compare favourably, in speed, and economy with crane relaying.

The task of so doing was entrusted to the author who evolved and designed the machine shown in figure 1.

The underlying principles of the relayer are simple. Two parallel tracks, one of which is being relayed are necessary for its operation and by internal balancing, the use of horizontal jibs and shallow lifting bales, it has been possible to condense the machine into the combined load gauge of two adjacent tracks and within this space all lifting and setting down operations are conducted, entirely clear of adjacent tracks and structures.

To describe the general layout of the relayer, a 40′ 0″ bogie wagon was obtained as a basis for its construction and upon this vehicle, two sturdy frames, one over each bogie, and 30′ 0″ apart were erected, to accommodate the winches, of which there are two, the jibs and the traversing balance weight. The winches are driven by compressed air stored in a receiver carried in an adjacent wagon, and a third wagon is used to accommodate a diesel driven air compressor. It is hoped that eventually a second bogie wagon will replace these two wagons, with a view to making a tider and more presentable job of this part of the unit.

Whilst the jibs operate in a fixed position, they are pivotted to facilitate travelling in train formation, and provision is made

for them to turn equally well, to either side of the wagon. Other features of the design are the traversing counter-balance weight and duplicate hose connections. The latter are fixed at each end of the vehicle so that should it be desirable to re-arrange the sequence of the vehicles at site, this can be done by simple shunt movements after having disconnected the hoses.

Fig. 1. — Track Relaying Machine.
The picture shows the second machine to be built—it is based on the original design, but embodies a number of improvements.

The machine is propelled by a steam or diesel locomotive, but the latter is obviously to be preferred in tunnel work.

The jib is secured in position by a single eye bolt 1 3/4″ in diameter, permanently attached to the jib by a pin in double shear. The jibs are almost self-balancing and therefore there is no appreciable change in the equlibrium of the machine whatever their position, until a lift is made.

The compressed air driven winches, of which there are two, were purchased as self-contained units known as the « Pikrose » No. 2 size single drum winch and this is a standard piece of haulage equipment normally supplied for colliery work. The mechanism comprises a three cylinder engine, contained within the drum, and developing 13 1/2 horse power. It is controlled by a lever throttle, clutch, reverse and brake. The direct pull on the drum is 1-3 tons and the rope speed is about 150 feet per minute at the working pressure of 60 lbs per square inch.

A 60′ 0″ length of track weighs 4-6 tons or 2-3 tons per winch. It is not essential to equalise the load between the winches by centralising the length of track between them. A sleeper pitch one way or the other is immaterial. After allowing for this, and friction in the ropes, a three rope

system of pulleys was found to give the best combination of lifting power and speed. The air consumption is heavy but intermittent, and a large receiver combined with a continuously running compressor, delivering 200 cubic feet per minute of free air, provides the power necessary to operate the unit to full capacity. The air inlet is 1 1/2″ diameter and both winches are fed from a 2″ main running the full length of the vehicle.

The receiver is 13′ 0″ × 4′ 0″ and the working pressure is 60 lbs. per square inch, plus a few lbs, to offset frictional losses in the piping. The four hoses are each 1″ bore to connect with the 2″ diameter air main on the bogie.

The counterbalance weight is an important feature of the design and comprises a nest of secondhand rails of 17 tons total weight, carried on cross carriages which in turn run on rolled steel sections set in a crosswise direction on the bogie. Travel is 22″ either side of the centre line of the vehicle and the traversing operation is carried out by hand wheels attached to screwed rods which drive die blocks set in the end carriages, all being integral with the structural steelframes erected over the bogie.

The counterbalance weight is so contrived to maintain a good and safe distribution of weight on the springs and wheels, during all conditions of loading and canting of track. This is essential to give full confidence in operating the machine quickly over points and crossings and in tunnels. The maximum variation in the loading of two wheels on an axle is in the proportion of two to one—or to put in another way, the centre of gravity of the machine with or without its load is always contained within the middle third of the wheel base. The springs attain their working load on a 3″ cant.

The are two lifting bales each comprising two steel channels housing two cylindrical plungers, which are operated by levers which work in a simple gate. The plungers engage the underside of the rails and the bale—as a unit—is safeguarded from slipping by two keeper plates which embrace the head of the rail.

Once the bale takes up the load, the plungers are automatically locked in position by the weight.

This is done by the introduction of flattened surfaces on the plungers which, contacting the underside of the rails under pressure, resist turning, and thereby hold the levers securely in the gates.

Tolerances are provided to accommodate variations in the depth of rail and gauge which arise as between worn track being taken out and new track being put in.

A funnel shaped piece of equipment assists in the butting of lengths of track as they are laid in. (Fig. 2.)

The following reference to the performance of the machine may be of interest.

It will operate anywhere where two tracks run parallel, separated by «six foot» ways of normal widths. Variation in the latter dimension can be met by an adjustment in the jibs at the beginning of the work and in this way variations between 4′ 6″ and 7′ 0″ can be made by increments of 3″.

Although within the load gauge, the jibs and bales are of sufficiently shallow construction to handle sections of track stacked five deep on a rail bogie.

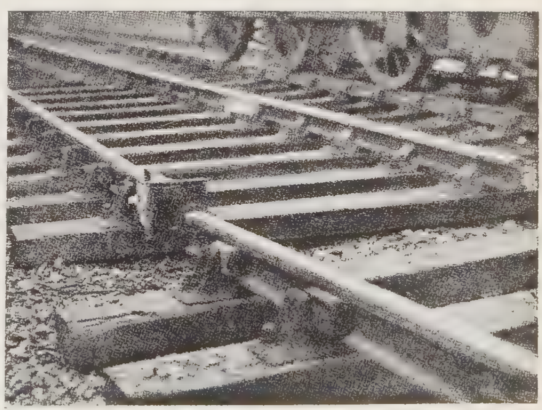


Fig. 2.

As a single operation, it will lift and load a 60′ 0″ length of old track and lay in its place a new section in 3 minutes.

After allowing for other operations such as breaking up the sleeper beds and moving up the material train as the work proceeds, a working speed of relaying ten lengths per hour can be maintained quite comfortably by a team of 20 men supported by 18 men breaking up the beds and 20 men following on packing, which after allowing for bonding and the blocking of lines, totals 65 men in all.

In four hours, 40 lengths or nearly 1/2 mile of track can be relayed with this set-up.

Relaying technique, with this machine, can be varied to a limited degree and I think I can safely say that this has been well explored by the Chief Permanent Way Inspector and his staff, to whom the credit of the sequence of operations now adopted is due.

The relaying accomplished in the first 10 months, is I think some measure of its success and amounts to :—

21 miles of running lines on the London East Division.

2 miles of sidings on the London East Division.

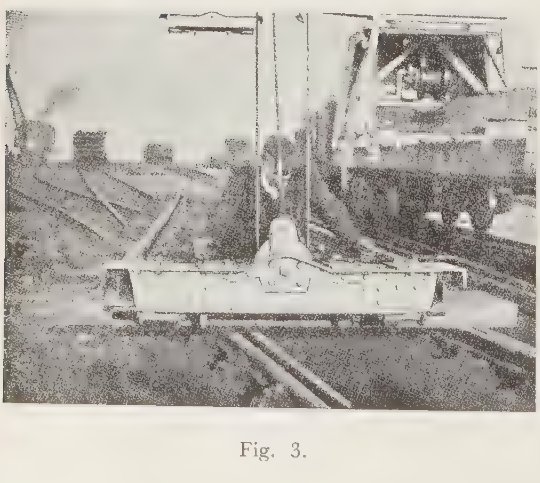


Fig. 3.

5 miles in running lines on other Divisions of the Southern and Midland Regions.

Although not specifically built for the Polhill Tunnel relaying, the construction of the machine was accelerated to have it ready for this work and apart from the trials, this was the first major relaying undertaken.

The construction of the machine has been accomplished at a time when industry is not well placed for the development of specialised machinery and « one off » jobs and in consequence the construction was undertaken in the divisional workshop from material available at the time, the design and construction being substantially completed in two months.

Compressed air was selected for simplicity and a full use of standard equipment has been made both in the choice of the winches and the compressors that drives them. The all-in initial cost of the machine is approximately a little more than half that of a steam crane of equivalent capacity.

A second machine has now been completed, in principle, the same as the first, but embodying a number of improvements.

First of all the contours at cornice height have been reduced to give improved clearances and freedom of access to the tightest places on this Region, and to maintain their original height, the jibs have been given an upward rake. The new jibs are telescopic and the radius is adjusted in that way.

The balance weight is now carried on carriages having roller bearings instead of plain and is traversed by a screw thread of improved design. The principle is the same, but whereas the traversing of the weight on the first machine is carried out by four men in seven minutes attention given to this detail has enabled the same operation to be carried out easily by two men in two minutes.

In addition, a cab at each end of the vehicle has been provided for the protection of the winch drivers. Those cabs have

sliding doors at each side and two end windows as well—all of which can be arranged to give protection from the weather combined with a proper view of the work in hand.

A modified lifting bale accommodates both bull head and flat bottom rail without adjustment of any kind. (Fig. 3.)

Apart from the economy effected by mechanisation, which can be measured in terms of hard cash, the saving in human effort by the use of this machine in tunnels and elsewhere, is in itself gratifying.

In conclusion, I should like to express my indebtedness to the Chief Civil Engineer for permission to use the material, around which this paper is written, and furthermore to voice my appreciation to Mr. Robertson and senior officers for the support given to this project.

[**621** .431 .72 (73)]

Budd diesel rail car has seats for 90.

(From *The Railway Age, September 17, 1949.*)

A self-propelled stainless-steel passenger car powered by Diesel engines, with hydraulic torque-converter transmissions, was introduced to the railroad industry by the Budd Company at Chicago on Monday, September 19. The car was driven to Chicago immediately after completion of extensive tests which were made on the Delmarva division of the Pennsylvania. The motive power consists of two 275-HP. General Motors Detroit Diesels, integral with each of which is a torque-converter transmission built by the Allison Division of General Motors. The engine and transmission unit is designed for operation with the center line of the cylinders a few degrees above the horizontal so that they can be mounted underneath the car body. This is an outgrowth of a wartime development which was used for the propulsion of heavy tanks.

Budd stainless-steel rail car powered by two G.M. Detroit Diesel engines mounted underneath the car.

The car is 85 ft. long, coupled, and because there is no encroachement of the power plant on the space within the body, it has comfortably spaced seats for 90 passengers, with a toilet and electrical locker and a vestibule cab at each end. It weighs 112 800 lb. ready to run. It is designed for use singly or in trains under multiple-unit control, with a single operator, and is intended for full-scale service on branch lines, for supplementary main-line service, and for commuter service.

The rail-motor cars built following World War I were largely developed as a means of reducing losses in the then declining local passenger service. They were less than fully qualified for main-line service and power plants occupied space within the car bodies. The new car is intended to provide an attractive service as far as passenger comfort and speed are concerned and to provide it on an economical basis by not encroaching on potential revenue space and by care in design to simplify maintenance. It is conceived to offer a means of restoring some

part of the local business which competing agencies have taken away from the rails during the 1920's and since.

Three types of interior arrangement will be available. One, the type already built, is a passenger car with seats for 90 persons which the builder designates RDC-1. Another will provide a 17-ft. baggage compartment and seats for 71. The third will have a 15-ft. railway-mail-service compartment in addition to the 17-ft. baggage compartment and will seat 49. These will be designated RDC-2 and RDC-3, respectively.

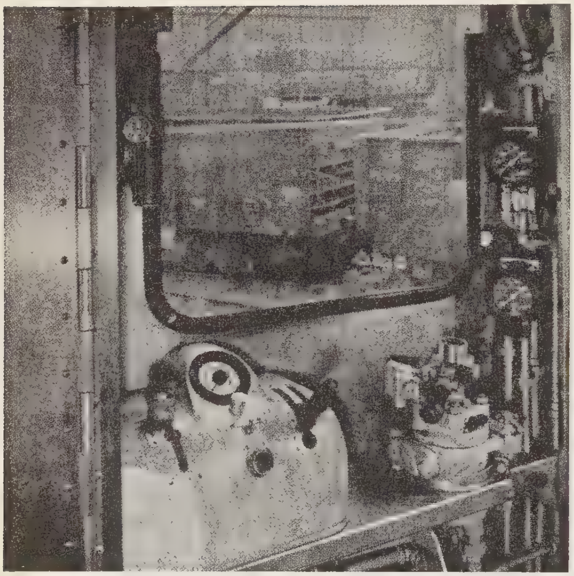
The car body is a stainless-steel structure, fabricated by the Budd Shotweld process. Unlike earlier Budd-built cars, the sides of this unit are girders, of which corrugated side sheets form the webs and to which are attached the outside fluted stainless-steel surface. The car is designed to meet fully the strength specifications of the Association of American Railroads. The center of gravity is 52.6 in. above the rail, an effect which is due in part to the location of the engines, transmissions and fuel tanks below the car floor.

The seats were especially designed. They are the walkover type, are comfortable in shape, and are low enough not to need footrests. This gives an unusually high space under the seat which adds to the leg room. Lighting is by fluorescent units in the center of the ceiling and lens type incandescent reading lights on the underside of the luggage racks over the seats.

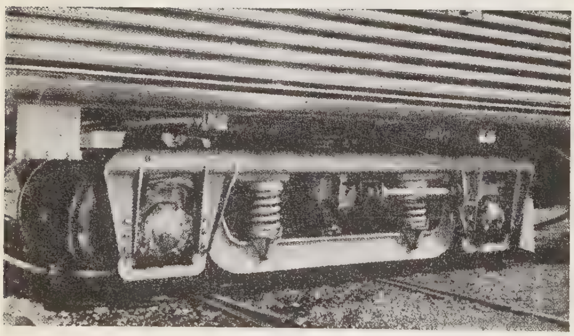
Partial bulkheads carrying the engine services to the radiators on the roof measure 19 in. longitudinally.

The power plant.

During the war there was a large demand for medium-size Diesel engines for use in armored tanks, small boats and landing craft for various branches of the military services. Because Diesel engines of the sizes needed were not available, it was necessary to utilize multiple-engine power plants. These were so successful that they have been continued in many commercial applications since the war. After the war the Detroit Diesel Engine Division of General Motors undertook the development of a



Operator's stand at the end of a vestibule.



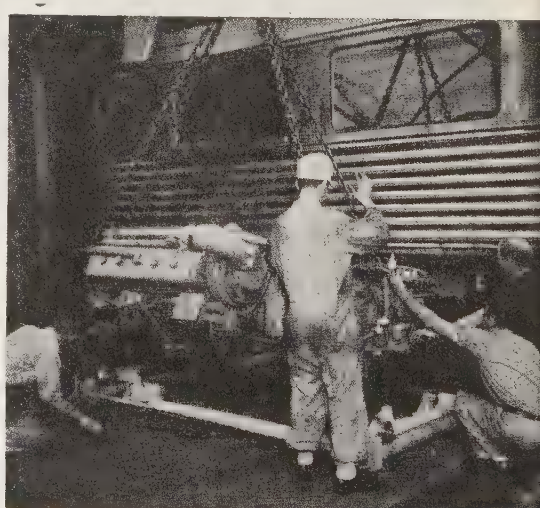
Truck frames are lightweight welded structures.

larger engine than that available during the war. This is the engine in use in the new Budd car.

There are a number of reasons for the selection of the 275-HP. two-cycle Diesel engine manufactured by the Detroit Diesel Engine Division for this service. It would have been impossible to employ one engine of the necessary capacity placed under the car without encroaching upon revenue space. Each engine can be placed adjacent to the axle which it drives, simplifying the mechanical connection between engine and driven axle. Each engine, being smaller in size and lighter in weight than a single power plant, is less difficult to remove for maintenance. The two-engine installation gives greater reliability than would a single power plant.

These engines are two-cycle, with the cylinders inclined 20 deg. from the horizontal. There are six cylinders in line producing 275 HP. at a governor speed of 1 800 r.p.m. A maximum torque of 860 ft. lb. is produced at 1 200 r.p.m. Each engine is supported at three points on rubber mounts and is enclosed in a demountable aluminum box, on the outside of which Neoprene has been applied as a sound deadener.

The torque-converter transmission was selected for its saving of several tons in weight, as well as for its effect on the cost of the car. The Allison converter is essentially a combination converter and fluid coupling, with a lock-up clutch for direct

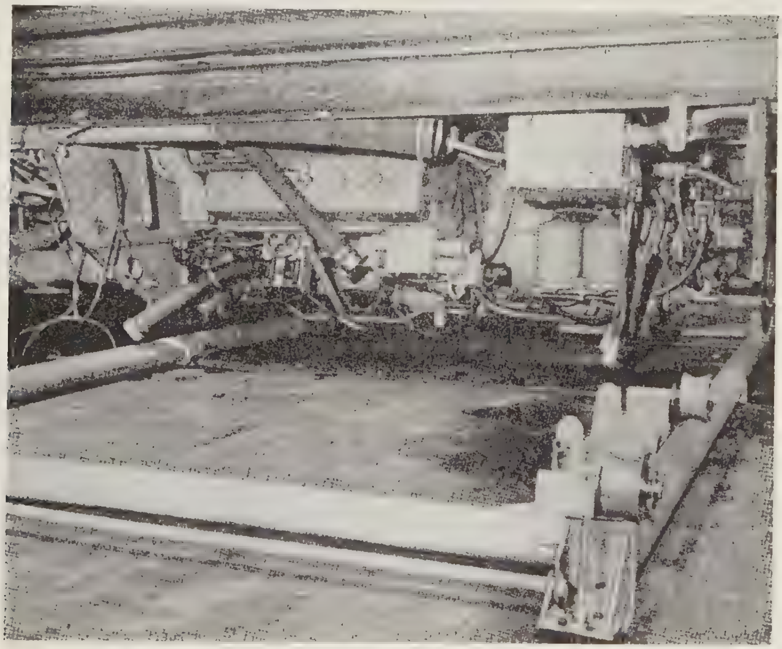


A power plant being lowered onto the dolly preparatory to installing under the car.

drive so that the torque converter is used during acceleration periods only.

The reversing is accomplished by means of two sets of constant-mesh helical gears, one or the other of which is engaged to an extension of the engine shaft by a hydraulically actuated clutch to suit the direction of car movement desired.

The engine-cooling radiators are installed on the roof of the car and are connected by piping to insulated water tanks under the car. The exhaust-pipe and water connections from each engine are housed in ducts which form a partial bulkhead near the middle of the car. The water from the engine passes first through a storage tank under the car. This would normally be the water circuit during winter weather. When additional cooling is required, thermostats open pipes which bypass the storage tank and lead through the radiators. When the water temperature rise above 160 deg., the cooling-fan motors on the roof are automatically started by thermostatically controlled electric circuits. These fans cycle on and off under the control of the water temperature. Tests indicate that the heat-transfer capacity of the cooling system is adequate for the highest atmospheric temperatures.



Transverse tubular rails in place under the car preparatory to removing a power plant.

Heat exchangers for the torque-converter fluid and lubricating oil form an integral part of the power plant. The pump which circulates the engine-cooling water delivers it from the storage tank or radiators, first to the torque-converter heat exchanger, then to the lubricating-oil heat exchanger, and then to the engine-water jacket.

The control system.

An operator's station is located at the right-hand side of the vestibule at each

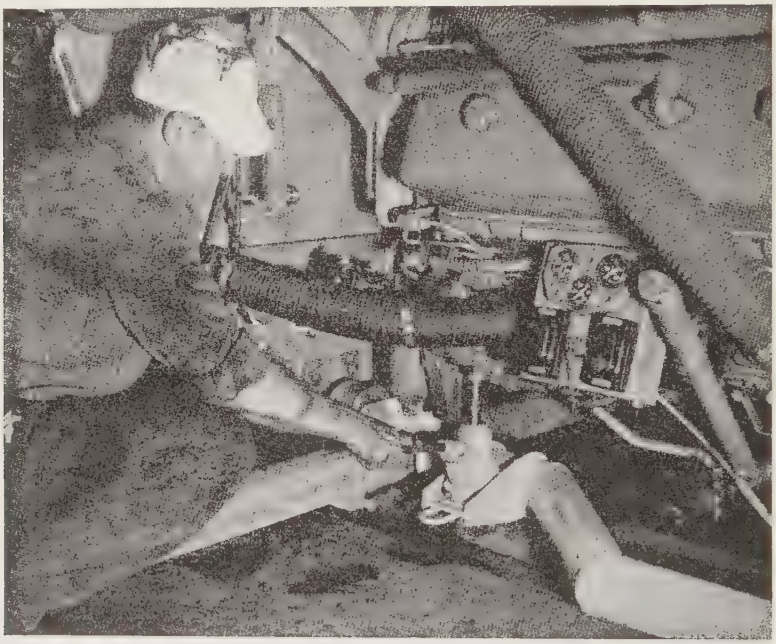
end of the car. There is a master controller, the engineman's brake valve, a bell-operating valve whistle cord, an electric heater, a windshield wiper and defroster. The master control box has two handles. The one at the left has three positions — one for forward movement of the car, a middle neutral or off position, and a reverse-movement position.

The right-hand handle has five positions. These are off, idle, second, third and fourth. The latter three operating positions represent one third, two thirds, and full crankshaft torque. The electric control circuits are interlocked so that the power-control lever cannot be removed from the off position until the direction handle has been set either in the forward or reverse position.

The torque-converter operates during acceleration up to a designated speed at which point the transmission automatically locks into direct drive. When decelerating, the direct-drive clutch is automatically released and the torque-converter restored to operation.

A foot-operated deadman's control, lighting switches and folding seat complete the equipment at the operating stand. With the control and brake-valve handles removed from the master control box and the seat folded down, the controls can be inclosed by swinging around 180 deg. the door which closes the end of the vestibule.

Each engine is started and stopped from the ground by push-button switches mounted on the side of the engine inside the housing.

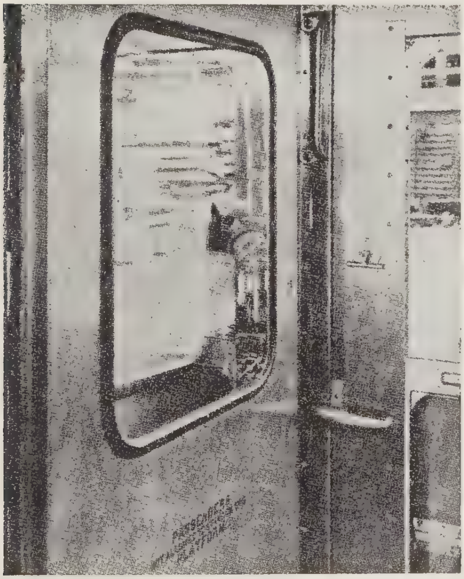


Operating one of the dolly jacks by which the engine is lifted in place. Engine starting and stopping buttons are shown at the right.

Electrical equipment and heating.

Provision is made for automatic protection of the engine against overspeed, overheat, or loss of lubrication. The pilot switches

for these functions are connected in parallel, the closing of any of which closes the engine inlet damper, cutting off the air supply, stopping the engine and releasing the transmission clutch. In the case of engine or transmission difficulty while the car is running, manual declutching and idling



The operator's station is inclosed when not in use.

is effected by a disconnect and shutdown switch in each electric locker for control of the engine at that end of the car only.

Electric power equipment consists of two 64-volt 10-kw generators, one of which is a part of each power plant. Batteries of 284 amp.-hr. capacity are carried in a stainless-steel box under the floor.

The car is air-conditioned by a seven-ton-capacity Frigidaire electro-mechanical system. Fresh air is taken in through screened openings at each side of the roof at one end of the car. This air passes through ducts to the plenum chamber. Recirculated air also enters the plenum chamber from the coach section. There are nine Anemostats through which the air enters the coach from the duct above the ceiling over the aisle.

The passenger compartments are heated by hot water circulated through finned radiator pipes at the usual location at the floor along the sides of the car. The water is drawn from the engine-cooling system and the car-heating radiators essentially take the place of the engine-cooling radiators during cold weather, Overhead heat is also supplied to the plenum chamber of the air-circulating system from the same source. The water is circülated by thermostatically controlled pumps, that for the floor heat being connected with the engine-cooling system of one power plant and that for the overhead heat with the engine-cooling system of the other power plant.

To prevent freezing during standby periods in cold weather live steam from a yard line may be fed to the cooling-water sump tank of each power plant through thermostatically operated valves. This maintains the temperature of the water in the tanks at 150 deg. F.

An overhead-mounted stainless-steel tank with a capacity of 75 gal. supplies water for wash bowls and toilets.

Trucks and brakes.

The four-wheel drop equalizer trucks are of special lightweight construction. The frames are built up by welding and have tubular side rails. The equalizers are forged I-beam sections, coil springs are used under the equalizers and swing bolsters and the bolsters are alined by longitudinal rubber-insulated anchor rods. The trucks have a wheel base of 8 ft. 6 in., 33-in. wheels and SKF roller bearings for 5 1/2-in. by 10-in. journals.

Each engine torque converter is connected to the inside axle of the adjacent truck through universals to a spline driving shaft and a Spicer drive assembly. The drive has a spiral bevel gear driving a ring gear incorporating a splined quill drive to the axle. A torque arm, which compensates for lateral motion of the axle, is resiliently connected to the truck transom.

The trucks are equipped with the Budd disc brake, Model CF, operated by New York HSC type air brakes with the D22 control valve. Two cast-iron discs are employed per axle, against the sides of which the asbestos-composition lining of the shoes operate. The shoes are applied against the discs by tongs, the long arms of which are forced apart by the pressure in the brake cylinder. During the test runs service stops were made without sand from 85 m.p.h. at a deceleration of 2.8 m.p.h. per sec. Emergency stops were made at 3 1/2 m.p.h. per sec.

For brakes operating at these high rates of retardation an anti-wheel slide device is essential. The Budd Rolokron system is applied on both trucks. This consists of the Rolokron, which is mounted on a journal box of each axle, and a control box to which are connected the circuits from the Rolokrons. These are inertia devices which operate under the action of an excessive rate of deceleration of the wheels to close contacts which operate an electric solenoid valve in the control box to release air from the brake cylinder and, under control of a time relay, to reopen the circuit and reapply air to the brake cylinder after about one second.

Under the control of the Rolokron sand is automatically applied to the rail when emergency applications of the brakes are made. The application is to the leading wheels of both trucks, depending upon the direction of operation. When a single pair of wheels decelerates, sand is automatically applied in front of them.

Sand boxes, each of 100 lb. capacity, have been installed in the sides of the car between the interior wall lining and exterior sheathing, one over each wheel. Access to these is through spring-loaded watertight covers in the sides of the car just below the belt rail.

One of the outstanding features of the power-plant installations is the simplicity of the attachment to the car body, Each power plant, consisting of the Diesel engine and transmission, a 10-kw electric generator, and oil coolers, is supported from the car body on rubber in compression at three points. Two of these are bolted connections at the transmission end of the plant and the other, tongue-supported in a suspension yoke.

It is not intended that more than minor adjustments and servicing are to be performed on a power plant while it is in place under the car. Whenever the engine and transmission need repair attention, provision is made for removing that power plant from under the car and replacing it with another, leaving the repair work to be done in a shop where all parts are accessible.

For the removal and replacement of the power plant a pair of rails of tubular section, spaced by tie rods at each end, are placed transversely under the power plant. Pads welded under these tubes support the frame on the track rails.

Running on the tubular rails is a dolly which supports three jacks, two at one end and one at the other. After the spline shaft and water and electric connections to the power plant have been separated, the dolly is rolled under the power plant until the jacks are in place under the pads on its under side. The jacks are then raised to support the power plant, the supporting bolts are removed from the transmission end, and the yoke in which rests the tongue at the other end of the plant is swung out of the way. The jacks are then lowered and the entire power plant rolled out from under the car where it can be picked up by crane for movement to the shop. Another plant can then be installed by the reverse process.

An engine has been removed from under the car by four men in 20 min. Based on experience to date, it is anticiped that a power plant can be disconnected, removed and replaced in an hour and a half.

Following the introduction at Chicago, the car will visit the major railway centers of the country for demonstration to railway officers.

Partial List of Materials and Equipment on the Budd Diesel Rail Car.

Steel castings	Pennsylvania Electric Steel Casting Co., Harrisburg, Pa.
End underframe, truck frame	Youngstown Steel Car Corp., Niles, Ohio.
Truck forgings	Canton Drop Forging & Manufacturing Co., Canton, Ohio.
Truck springs	Union Spring & Manufacturing Co., New Kensington, Pa.
Shock absorbers—bolsters	Monroe Auto Equipment Co., Monroe, Mich.
Anti-wheel slide device : disc brakes	Budd Co., Philadelphia, Pa.
Coupler and yoke	National Malleable & Steel Castings Co., Cleveland, Ohio.
Draft gear	Waugh Equipment Co., New York.
Journal bearings	SKF Industries, Philadelphia, Pa.
Hand brakes	National Brake Co., New York.
Air brake system	New York Air Brake Co., New York.
Insulation and sound deadening	Gustin-Bacon Manufacturing Co., Kansas City, Mo.
Diesel engines	Detroit Diesel Engine Div., General Motors Corp., Detroit, Mich.
Torque converter	Allison Div., General Motors Corp., Indianapolis, Ind.
Axle drive unit; generator drive	Spicer Manufacturing Div., Dana Corp., Toledo, Ohio.
Engine controllers; cooling and ventilating fans	Westinghouse Electric Corp., Pittsburgh, Pa.
Radiators	Harrison Radiator Div., General Motors Corp., Lockport, N. Y.
Muffler	Burgess-Manning Co., Libertyville, Ill.
Battery	Electric Storage Battery Co., Philadelphia, Pa.
Electric generator and controls; ceiling light fixtures	Safety Car Heating & Lighting Co., New York.
Electric wire and cable	General Electric Co., Schenectady, N. Y.
Air conditioning	Frigidaire Div., General Motors Corp., Dayton, Ohio.
Air distributors	Anemostat Corp., of America, New York.
Air filters	Air Maze Corp., Cleveland, Ohio.
Air grills	Barber-Colman Co., Rockford, Ill.
Heating system and accessories	Vapor Heating Corp., Chicago.
Drop sash, parcel racks	Adams & Westlake Co., Elkhart, Ind.
Window glass	Pittsburgh Plate Glass Co., Pittsburgh, Pa.
Panels and doors	Haskelite Manufacturing Corp., Grand Rapids, Mich.
Vestibule flooring	Alan Wood Steel Co., Conshohocken, Pa.
Floor covering—plastic tile	Johns-Manville, New York.
Coach seats	Heywood-Wakefield Co., Gardner, Mass.
Hoppers	Duner Co., Chicago.
Lavatories	Crane Co., Chicago.

[624 .91]

The use of synthetic glues, in particular in large wood structures.

(Génie Civil, 15 Feb. 1948.)

Until recently all glues in use (skin, leather, bone, fish, strong glue; starch or flour paste, dextrine, gum arabic) were either animal or vegetable in origin. They are still used for domestic purposes, by workmen, and in many industries, as they are easy to make from raw materials in plentiful supply and of relatively low price.

A first evolution was seen when casein, extracted from skim milk and of restricted use, was used in considerable quantity to make plywood. Then certain industries in which wood was used in great quantity, such as the aeronautical industry, came up against certain problems which the ordinary glues could not solve. Plastic materials which had been developed in the meantime were considered. This solved most of the problems, either by using new synthetic products or by these in conjunction with the old glues.

During the second world war, the impossibility of getting the raw materials for the old glues (1) gave a further impetus to the new adhesives. These are now frequently substituted for the old because they give better results and because they enable certain problems in which their use had not been foreseen to be solved, such as the construction of large wooden structures.

Advantages of gluing wood.

The advantages of gluing wood have been reported by M. J. Campredon, Conservator of Waters and Forests, in a lecture he gave on the 4th Feb. 1947 at the « Institut technique du Bâtiment et des Travaux publics » (1).

The principal advantage is that by gluing the mechanical strength of the wood resulting from its fibrous texture can be used to the full. This strength may be increased by the use of suitable adhesives and methods of gluing.

A further advantage is that it is not always essential that the surface of the wood in contact with the glue shall be perfectly level and planed. Some glues are suitable when the surface is rough and as it came from the saw.

The whole of the available glues are far from being satisfactory in large structures. The old glues are affected by humidity : the good casein glues stand up to dampness fairly well but in general are not very stable in the presence of water. They are subject to attack by organisms which cause rot and decay. For this reason fungicides and antiseptics such as sodium fluoride are sometimes incorporated in the solution.

The synthetic adhesives were not used in structural work before 1934. They are in constant use in Switzerland where for centuries the Swiss have mastered the technique of large wooden structures. Adhesives using casein were in use in 1920; up to now the structures so glued together have stood up well and it is thought that adhesives with synthetic resin will give at least as good results.

In France, almost the only glues used are those of the phenolformol (bakelite) and ureaformol (caurite) group. Both

(1) The Germans were very hard hit in this respect during the last war, and they invented some 15 new synthetic glues. Some of them are emulsions of polymeric products, whilst others set owing to the polymerisation of their synthetic constituants.

As regards these glues, their commercial names, their properties and their use, with or without mineral admixture, see A. PETZ : « Synthetic glues in competition with animal and vegetable glues) » (*Chemiker Zeitung*, 16 Feb. 1944).

(1) The text of this lecture with many illustrations was reproduced in the Note No. 20, series H, of the 5th May 1947, of the Institute in question. The information we give hereafter is taken from it.

liquid and powder forms, cold and hot, are employed. Considerable care is needed in use. The wood cracks or splits if the thickness of the glued joint exceeds some tenths of a millimeter. It is as well therefore only to use certain adhesives made of casein, melamine-formol and urea-formol, amongst which can be grouped the Melocols made by the Swiss Company C.I.B.A. (from the first letters of Chemistry and Bale) made and sold in France by the Saint-Gobain Company. We will deal with these later.

Gluing technique.

In structural work, usually relatively narrow and thin strips are assembled by gluing to form a large and deep member for use for example as a bent rafter or a straight girder. The gluing is done in the shop by cramps under a certain pressure and temperature (Fig. 1).

A cold glue with a catalyst known as a hardener to accelerate its setting becomes too viscuous if not used within two or three hours. If the shop temperature be 15° C. (59° F.), the time to dry under 5 kgr/cm² (71 lbs per sq. inch) pressure will be three hours; 5 to 6 hours if the temperature is 10° C. (50° F.) and only one hour if the temperature is 20° C. (63° F.). It is estimated that a drop of 5° below 20° C. makes it necessary to double the time needed to dry under pressure and in consequence the time during which the gluing material is in use. Inversely an increase of temperature of 5°, makes it necessary to work quickly, which can be difficult if the member is large or complicated.

When using strips of wood, the surfaces can be coated by passing them through a gluing machine of the roller type for example. Once coated, the strips are placed in a mould or a form of the desired shape, putting the wedges in position when used, or the cramps to be tightened later. A cramp is used every 24 to 30 cm (9 7/16″ to 11 13/16″). The cramps may be of the chain type if the part is large in cross section.

Before gluing the humidity of the strip of pine or deal should be below 12 to 15 % and the density of the wood not less than 0.45. The drier the wood the better.

Usually the strips are passed through a drier; they are then trimmed and planed if the joint thickness is to be kept below 0.3 to 0.5 mm (3/256″ to 5/256″).

The wood should be straight grained; in Switzerland the regulations allow a maximum inclination of 12 %; the diameter of any knots must not exceed 1/8 of the width of the strip in the parts under tension where preferably no knots should be allowed, and not more than 1/5 in compression or bent parts. Strips 19 to 20 cm (7 1/2 to 7 7/8″) give the best results in structures.

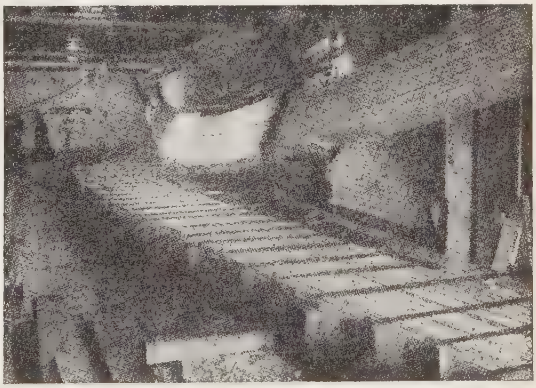


Fig. 1. — Making in the shop a curved rafter of glued wood 45 m (147′ 7 3/4″) span Hetzer system.

The details most used in glued structural members are straight girders of rectangular section usually in pairs separated by a space in which are distance washers over the bolts : each of these is 16 to 18 cm (6 5/16 to 7 3/32″) wide and 0.60 to 1.20 m (1′ 11 5/8″ to 3′ 11 2/8″) deep, equal to about 1/15 of their span which quite frequently reaches 20 m (65′ 7 3/8″).

In building up these members, a mould is used formed of a sole plate and uprights between which the strips are laid on coming from the gluing machine. They are temporarily held by pins driven at an angle from

the top, which are easily withdrawn when the clamps have been placed.

Synthetic glues. — The chief synthetic glues are the melocols with a resine formol base; they are sold as a powder soluble in water. When preparing the glue a hardener has to be added; if necessary a charge can be added; the mixture is dissolved in water. The glue so obtained is fluid but slowly becomes viscuous and has to be used before it becomes too stiff.

The joints obtained from these two products are such that under a sudden overload, it is the wood which gives and part remains adhering to the joint. The joint resist water, heat, mould and xylophagous insect attack.

Melocol H. — This is an urea formol derivative; it sets at atmospheric temperature or hot. It is used with one of the three following hardeners :

1) 205 hardener, suitable for cold or hot gluing; it is a white powder soluble in water and about 10 % is added to the Melocol. The glue remains liquid two to three hours;

2) 307 hardener; a liquid of which also 10 % is added. The Melocol hardens more slowly than with 205; it is used when the temperature of the shop exceeds 10° C. (50 F.). This hardener is used only rarely in large structures.

3) 317 hardener; a liquid of which 10 % is added for working at 80° to 100° C. (176° tot 212 F.). The glue remains liquid for 18 to 24 hours. This glue is hardly usable except hot; in structural work it is necessary to employ high frequency heating involving special equipment.

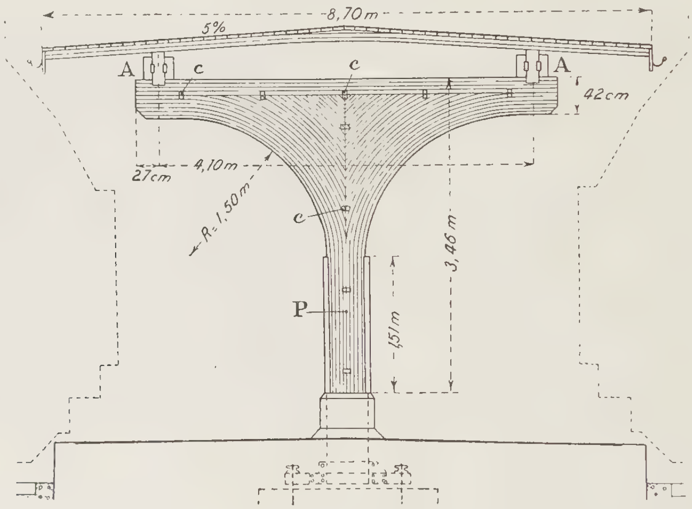


Fig. 2. — Section of the glued wood platform roof at Daniken station (Switzerland).

The addition of a charge reduces appreciably the cost of the gluing without any marked reduction in the strength of the joint : its advantage is that the surface of the strips can be rough and the wood porous as the glue penetrates between the high points and fills the pores.

The charge cannot be anything; the recommended additions are :

1) the charge G, a mineral; it is a white powder, used up to 50 % of the weight of the Melocol H; it increases the resistance to humidity but it has the disadvantage that if it has to be machined, the cutters wear quickly;

2) the charge W, a light brown powder based on vetch flour; up to 3 times the weight of the Melocol can be added. This charge is more affected by humidity than G; generally it is not used in glued structures.

Melocol H, hardeners and charges should be stored separately in tight containers; under such conditions they keep several months. When mixed they should not be kept so long.

The glue is prepared in really clean vessels, of wood, pot, enamel or aluminium, but not of copper or brass. If there are any lumps in the melocol, they are rubbed by hand to dissolve them. The hardener in powder form and the charge are added dry, then the water, and well stirred, in a mixing machine if large quantities are being prepared.

This glue should be free from lumps and as thick as possible, about the consistency of fresh honey. The quantity of water added should be such that when the joints are clamped down, the excess oozes out in a mass, not in drops. As an example the composition by weight of universal glue, which is specially suitable for joinery and Hetzer system structures, is :

Melecol H in powder.	100
205 Hardener in powder	10
Charge G in powder	50
Water.	70

The base solution can be prepared in advance and will remain good one or two weeks, as for example by dissolving the Melocol in its own weight of water and adding the hardener and charge just before use.

The quantity of glue to be used depends upon several factors and in particular on the pressure on the joints; in the case of structures it varies from 200 to 600 gr/m² (5.9 to 17.7 ounces per sq. yard) of the area of the joint. The period of clamping varies with the kind of hardener, its proportion (5 to 20 % for the hardener No. 205), and the drying temperature (from 10 to 40° C. = 50° to 104° F.). The extreme periods are 20 hours and 30 minutes.

Melocol M. — This is of melamine-formol; it gives joints which are not affected by boiling water if the wood has been glued at 105 to 110° C. (221° to 230° F.). The hardeners Nos. 205 and 307 are used, preferably with charge W. The storage of the constituants, the preparation of the glue and its use demand the same care as Melocol H. The clamping pressure can be as high as 25 kgr/cm² (355 lbs per sq. inch) for some wood. The Melocol M is especially suitable for veneered wood and panels; it is not used on glued structures.

Applications.

Zurich goods station sheds. — The sheds covering a total area of 5000 m² (5 980 sq. yards) were built in 1944-1945 by Dr. Staudacher. The roof is carried by twin girders in glued wood of rectangular section carried on pillars 40 m (131′ 2 3/4″) apart on which rest near their articulated ends the transverse girders spaced 3.33 m (4′ 3 3/16″) apart, these having a section of 16 × 48 cm (6 5/16″ × 1′ 6 7/8″) or 16 × 85 cm (6 5/16″ × 2′ 9 1/2″) with spans of 6 or 9 m (19′ 8 1/4″ or 29′ 6 3/8″). The roof is covered with bituminum paper covered with fine gravel attached to battens carried on rafters.

Platform roofs of the stations at Sissach, Liestal and Däniken (Switzerland). — The passenger platforms of these three stations have had roofs (Fig. 2) in glued wood, consisting of brackets built into their supporting piers P of 46 × 46 cm (1′ 6 1/8″ × 1′ 6 1/8″) on the ends of which are carried the longitudinal twin girders A, 43 cm × 16 cm (1′ 4 15/16″ × 6 5/16″) square. The

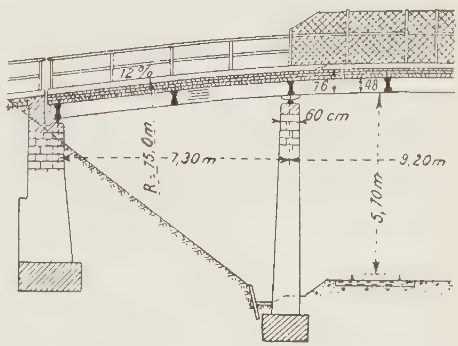


Fig. 3. — Overbridge in glued wood at Riviera Taverne on the St. Gothard line (Switzerland).

12 mm (15/32″) thick strips are assembled at regular intervals at the connecting joints which are not parallel to them by oak keys *c*. The piers are strengthened by straps tightened by galvanised bolts. They rest on masonry bases and are anchored to the reinforced concrete foundation.

These piers carry the transverse girders which make rafters to which are nailed the battens of the roof covering in Aluman sheets (1). 20 dm³ (1 220 cubic inches) of glued wood per sq. m (1.196 sq. yard) of area covered was used.

Other works. — Two foot bridges on the St. Gothard line have been built recently in glued wood, to replace level crossings.

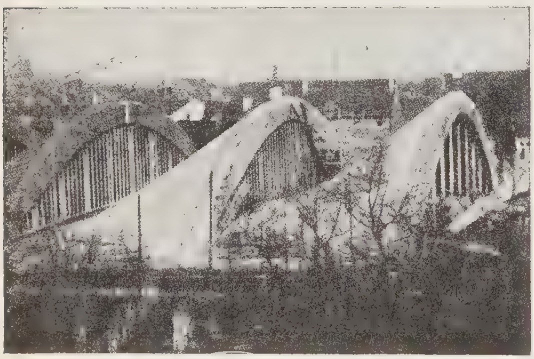


Fig. 4. — Hetzer system glued wood roof of the Grand Hall of the Bale Sample Fair, built in 1944-1945.

The Riviera-Taverne bridge (Fig. 3) consists of two arched twin girders 25 m (82′ 1/4″) long carried by two piers and masonry abutments. The foot path in wood is carried by cross girders in glued wood of double T section. As this structure is exposed to the weather, the strips of the foot path have been impregnated and the girders given several coats of linseed oil paint and then two coats of a water resistant paint.

The bridge has a total width of 3 m (9′ 10 1/8″), 2.50 m (8′ 2 7/16″) for vehicles with 8 ton axle load.

Roof of the Grand Hall of the Bale Fair. — This roof on the Hetzer system (Fig. 4 and 5) is one of the most remarkable structures in glued wood to be built in Switzerland recently. It consists of arched triple articulation rafters of 45 m (147′ 7 3/4″) span and cross stays acting as ties. Such lean to roofs ensure excellent lighting.

Arch scaffolding. — Glued wood structures also lend themselves to the building of arch scaffolding in the form of trellis, the bars of which are assembled together and to two bases in glued strips. Such arches were used as scaffolding in building in 1944-1945 the Junction Bridge over the Rhone at Geneva. This bridge was described in the *Génie Civil* of 15th Nov. 1946; it is in masonry and has three arches, one of 57.90 m (189′ 11 1/2″) span and 19.35 m (63′ 5 3/4″) height.

The glued wood scaffolding can be made so that it can be taken down and so be used again.

***

By a careful selection of glues and glued wood large structures can be built rivalling large metal structures and having certain advantages over the latter. Glued wood is only making its debut : it will be improved and will find applications in other fields than large structures. Progress will be made in the manufacture and use of synthetic glues.

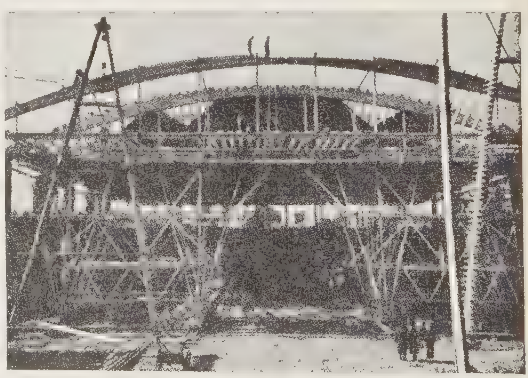


Fig. 5. — View taken during the erection of the roof of the Grand Hall of the Bale Fair.

(1) Aluman is an alloy of aluminium and manganese made by the Aluminium Industry Co. of Lausanne, a thin sheet being used like zinc for roofing. See *Génie Civil*, 1st Dec. 1946, p. 335.

NEW BOOKS AND PUBLICATIONS.

[385 .02]

The Universal Directory of Railway Officials and Railway Year Book, 1949-1950. — London : The Directory Publishing Company Limited, 33, Tothill Street, Westminster, S. W. 1. — 632 pages ($8\frac{1}{2} \times 5\frac{1}{2}$ in.). (Price : 30 s. net.)

The Universal Directory of Railway Officials and Railway Year Book 1949-1950 reaches with the present volume its 55th year of publication.

The first edition was compiled from official sources and issued in 1895, and at that time some 270 pages sufficed to cover the text including an index to countries, an index to names of railways and the comprehensive personal index of railway officials which is still a noteworthy feature of the volume.

The present edition should prove at least as valuable as its predecessors in containing within the scope of little more than 600 carefully-condensed pages more comprehensive lists of officers and particulars of railways throughout the world than can be obtained from any other publication in any language.

The information contained in this volume enables railway officers and others to keep in touch with the personnel on railways throughout the world for the exchange of information concerning research and developments in all phases of railway operation and maintenance.

The continuance of the policy of nationalisation in many parts of the world has further reduced the number of privately owned railways outside the North American Continent and the important foreign financial interests in railways that were exemplified by the British investments in Argentina and Uruguay are virtually extinct.

Political changes have affected the status of many parts of the British Commonwealth, and all entries are divided into one of two main divisions, namely, British Commonwealth (regardless of dominion or colonial status) and Foreign. Each of these sections is again subdivided geographically into Continents as follows :

Europe, Australia and New Zealand,
Asia, North America,
Africa, South and Central America.

For ready reference purposes at the end of the volume will be found three indexes :

1) an index to countries;

2) a general index including all references to railways and statistical and other information;

3) a personal index of railway officials.

[385 .6]

List of multilateral conventions, agreements, etc., dealing with transport and communications. — Published by the United Nations, Department of Economic Affairs, Transport and Communications Division. — One brochure (6×9 inches) of 92 pages. — 1948, Lake Success. (Price in the U. S. A. : $ 0.75).

The Economic, Financial and Transit Department of the League of Nations published a document with the same title. When the General Assembly of the United Nations held its first session in London from the 10th January to the 14th February 1946, it invited the Economic and Social Council to take over and carry on the duties

previously falling to the S. D. N., especially as regards research work and statistics. The present document which contains a list of the principal international obligations as regards transport and communications is the result of this decision.

The list includes 219 conventions and agreements grouped under the following headings: 1. Liberty of transit. 2. Navigation and maritime ports. 3. Inland navigation. 4. Railways. 5. Road traffic. 6. Air traffic. 7. Post Office and Telecommunications. 8. Identity and travelling cards. 9. Tourist traffic. 10. Electric power. 11. Various.

As regards the railway, besides conventions of somewhat limited interest, the list includes those of a general character such as Technical Standards, and those regulating the international services for the transport of goods on the one hand and passengers and luggage on the other. On the other hand, no mention is made of certain conventions widely used in Europe, concerning the exchange of wagons and coaches in the international services (R.I.V. and R.I.C.).

An appendix includes the titles of all the conventions and agreements concluded under the auspices of the League of Nations. Another gives the sources to which reference is made in the general list. Finally, another appendix gives the articles of the peace treaty concluded after the second world war which deal with transport and communication matters.

An introductory passage stresses the special care with which all the data have been selected, chosen and analysed, whilst explaining why it is not possible to guarantee that the documentation is entirely exact and complete. This is our justification for pointing out the gap in the conventions relating to the railway. But this does not spoil the value of the documentation which is of the greatest value for all those interested in international questions.

E. M.

[**69** (09 (493)]

Annales des Travaux Publics de Belgique. *Jubilee Number* (1843-1948). — One volume (9 ½ × 12 1/4 inches) of 216 pages, copiously illustrated. — 1949, Brussels, published by the *Annales des Travaux Publics de Belgique*, Résidence Palace, 155, rue de la Loi. — Printer-distributor : Imprimerie G. I. G., 61, avenue de la Liberté, Brussels.

The *Annales des Travaux Publics de Belgique* celebrated its hundreth year of publication in 1948.

The Management Committee of this valuable scientific review had the happy idea of commemorating this centenary by publishing a 1843-1948 jubilee number.

It may perhaps be of interest to recall that these Annales, the official organ of the Ministry of Public Works, founded under the auspices of the Belgian Government are a collection of scientific, industrial and administrative papers, dealing primarily with the art of building and communications by road, rail and water. They include everything to do with the exact sciences, and are of interest not only to all the builders of the country, but also to all the erudite whose researches may culminate in practical applications and improvements to the art of building.

This vast field of action is explored in all the syntheses published in the special number.

The brightest lights of the technical corps in Belgium responded brilliantly to the initiative of the Management Committee of the *Annales*. This publication can claim the honour of initiating the movement which gave birth to the idea of creating the National Research Funds, with which the name of the great King Albert 1st is closely connected.

Under the title « Réminiscences » at the

beginning of the special jubilee number, the President of the Management Committee of the *Annales,* M. DEVALLÉE pays a tribute to the memory of this enlightened sovereign.

We have not sufficient space to give many details about the technical memoirs presented. It is however possible to classify them according to the different activities of the Bridges and Highways, Belgian National Railways, and Civil Engineering sections of our Universities.

Roads, waterways, and buildings are all the subject of studies whose great interest and importance to the experts must be stressed.

The General Manager of the Bridges and Highways Department, M. DEVALLÉE and his assistants Messrs BIJLS, BLOCKMANS, CAULIER, CLAEYS, DE BEER, DE COCK, PICALAUSA and WILLEMS have made brilliant contributions thereto.

Modern tendencies in the construction of bridges, both railway and road bridges, have been described by Messrs DESPRETS and DE CUYPER, whose great experience and high professional status are well known to all Belgian Technicians.

Our practical engineers, Messrs DELENS, DE VOS, DUTRON, HOLOFFE, NIHOUL, SPRUYT and TASSIN, explain the evolution during the last decades of the different techniques with which they are familiar in studies which are necessarily brief but extremely interesting.

The problem of raising the Nord and Midi Stations in connection with the Junction, a work which has preoccupied Belgian technical literature for many years, is the subject of a clear and opportune report by M. OLIVIER, Assistant General Manager of the Belgian National Railways. He has succeeded in bringing out the difficulties which have had to be surmounted in carrying out a work of such magnitude, which has taken so long, and expresses the hope that it will be possible this time to bring this work, interrupted by two wars, to a happy conclusion within a very short time, to the benefit of the whole population of Belgium.

Finally we should like to draw the attention of the scientific world to the original articles by our University Professors, Messrs BAES, CAMPUS, DE MARNEFFE, DE SMET, MAGNEL and TISON, each of whom writes in a masterly fashion about the questions in which be is most interested.

Professor VAN HECKE, President of the Permanent Committee of the Belgian National Railways, ends the series of memoirs by stressing the necessity and utility of technical control of the proposals, calculations and execution of work by private builders and Public Works Department. He renders homage to the founders of this institution with which the Assurance Companies are in collaboration as is only logical, thus ensuring both assurance and control, born of the profound and rapid evolution of methods of calculation and working.

The presentation of this jubilee number, which is copiously illustrated, is faultless; it conjures up a past of which all Belgian builders can be justly proud; it stresses present day achievements, and co-ordinates the efforts of our research workers and practical experts.

The *Annales* still constitute for the young the best means of improving their knowledge; they maintain the repute of Belgian builders abroad, and the jubilee issue now under review, a real synthesis of the art of building, is without doubt a guarantee of success for the future, for as M. BEHOGNE, the Minister of Public Works states at the end of the foreword : « the hundred years experience now lying behind this institution is the surest guarantee thereof. »

J. D.

[**385.** (091 (44)]

LARTILLEUX (H.). Former pupil of the Polytechnique School, First Inspector on the French National Railways. — **Géographie des Chemins de fer français.** *Premier volume :* **La S. N. C. F.** *(The Geography of the French Railways. Volume One : The French National Railways.)* — One volume (7 $^7/_8$ × 11 $^3/_4$ in.) of 338 pages with numerous illustrations and photographs and 10 coloured maps. — *Deuxième volume :* **Réseaux divers.** — *(Volume Two : Various railway systems.)* — One volume (7 $^7/_8$ × 11 $^3/_4$ in.) of 254 pages, numerous illustrations and 8 coloured maps. — 1948, Paris, Librairie Chaix, 20, rue Bergère.

These two volumes are the first of a series which the « Librairie Chaix » proposes to publish under the general title *Géographie Universelle des Transports* (Universal Geography of Transport). The next volumes will be devoted to the *Road.* These will be followed by volumes dealing with *Air transport, Maritime transport* and finally *Electric Power* and *Telecommunications.* This shows that the scope of this series is a considerable one.

To make the position clear, the author explains in his foreword that neither technique nor history are concerned. He has merely wished to give a true picture of actual transport lines, showing their geographical distribution throughout the world. To judge by the first volume, the general idea has been well fulfilled. The description of the layout of the lines and their profile, the configuration and contexture of the lines is completed by details concerning the country through which they run and its orography and hydrography. At the same time the railway specialist is given a clear idea of the diversity of traffic from one line to another and how the amount of traffic has affected the general technical structure of the lines.

Special attention is given to the lines leading to beauty spots. This is justified by the increasing value and continual development of tourist traffic, as well as the number and boldness of conception of the structures.

The *first volume* deals with lines operated by the S. N. C. F. The plan on which it is based differs somewhat from the present regional divisions, being more in line with the geographical divisions of the country. With Paris as his base, he describes in turn the great imperial line (Paris-Lyon-Marseille-Côte d'Azur), the lines to the Alps and Jura, the Nord and Est, and the Ouest region, the lines of the old Midi system, and finally the lines to the Central Massif.

On the journeys on which he invites his readers the author provides an agreeable mixture of substantial technical facts and geography plain and simple, as well as commercial and industrial geography. He gives plans showing the successive changes in the large stations, especially the stations of Paris. Outline drawings of remarkable clearness show the layout of the lines on the outskirts of all towns of any importance.

Other drawings show the topography of a whole district. Others show the general layout of large towns or important ports, with particular reference to the railway installations. In addition coloured maps to a scale of 1/1 500 000 cover the whole of France and her coast line and show the layout of all the railway lines side by side with the rivers and the country in relief.

All the lines in existence at various epochs are shown on the general maps based on a brief historical review, the earliest going back as far as 1850.

Though these outline drawings are extremely expressive, their interest is perhaps exceeded by the other illustrations consisting of photogravures of celebrated structures, new stations, modern trains, hydro-electric stations, mountain lines, etc.

Though not wishing to deal with historical questions, the author has however explained at the beginning of the various chapters how the main line railways which were amalgamated into the S. N. C. F. on the 1st January 1938 were constituted.

The increase in traffic made it necessary to double or quadruple lines. This was the case with the imperial line, so called because of the traffic it assures in France, towards Italy and abroad via the port of Marseilles. This example is characterised by the influence of the water courses and the contours of the country. A modern method which will probably be applied is the standardization of the lines thanks to perfected signalling methods.

The *second volume* describes French lines other than those of the S. N. C. F. It includes three chapters : the first devoted to the secondary railways, the second to the urban lines (Paris metro, tramways and bus lines of the provincial towns), and the third to the mountain lines (rack railways, funiculars, and aerial lines).

These methods of transport differ a great deal as regards their equipment, traffic, regions served, and train frequency, but their importance is considerable as they are an indispensable complement to the main lines, and the last named reach places where no railway is possible.

With them the geographical aspect of transport is still further stressed, and the illustrations are still more copious and diverse. Black and white drawings alternate with coloured maps and it may be said that no corner of France has been left unexplored. The photogravures show very picturesque views, even in the first chapter, since the secondary railways also include mountain lines.

It is in the third chapter however above all that audacious achievements can be admired the triumph of technique over the difficulties accumulated by nature. We will only mention the Chamonix-Col du Midi aerial line the third section of which carries passenger to 3 650 m. (11 975 ft.) above sea level into a world of ice and glaciers.

It is clear that the object aimed at by this book has been fully realised. In the interior of the country as on the furthest frontier outposts, in the large towns as in sparsely populated regions, the author has successfully shown how the railway has been adapted to the geographical conditions met with in order to satisfy the most diverse requirements. In the conclusions to the chapters and the more general conclusions at the end of each volume, a picture of the whole is given, supported by the most significant figures which underline the efficacity of transport in the economic life and development of civilisation.

In addition, the perfect execution, the beauty of the text and the careful arrangement and presentation of these two volumes makes it a pleasure to read them and is worthy of the publishing house of Chaix.

E. M.

[**385** (09 (44)]

S. N. C. F. — 1944-1948. — Supplement to the review « *TRAVAUX* ». — One volume (9 ½ × 1 ¼ in.) of 332 pages, copiously illustrated. — 1948, Paris, Editions « Science et Industrie », 6, Avenue Pierre 1er de Serbie. (Price : France et Union Française : 525 francs. — Foreign countries : 585 French francs.)

This special publication issued by the *Editions Science et Industrie* as a supplement to the periodical « Travaux » is dedicated to the renaissance of the French National Railways since the liberation.

The trials undergone by the French Railways during the war are well known.

The figures which have been published in this connection are very striking. In the preface, he wrote for this handsome volume, M. LEMAIRE, the General Manager of the French National Railways, gives a striking picture of the state of the railway at the time of the liberation. To mention only the rolling stock, at that time only one fifth of the steam locomotives, one third of the goods wagons and one fifth of the passenger coaches were still usable. The most important method of transport, so essential to the economic life of the country, had almost been brought to a standstill. There was an urgent and immense task to be undertaken.

In this preface also M. LEMAIRE gives a brief description of the means by which the train services were started again on most of the lines, in spite of the poor resources available, and the principal stages of restoration, the rapidity of which impels our astonishment and admiration.

At first however it was only question of provisional constructions and temporary repairs, except in a few cases where circumstances made something better possible. After this initial phase, however, the S. N. C. F. was able to set about its permanent reconstruction. The interest of this book lies therein, as this reconstruction was not limited to restoring the former position but was linked up with a vast programme for improving the system. This covered profound reforms affecting both the passenger and goods services. A ten year plan was drawn up immediately after the war, and all the work so far accomplished has been based on this plan.

The various chapters of this plan which are merely sketched in in broad outlines in the preface are dealt with in detail in the book itself. They are the subject of different notes written by specialists, each of whom reports on the stage reached in his own domain as regards the technique adopted to carry out the plan.

The articles are classified and grouped under three headings: I. Roadbed, permanent way and buildings; II. Rolling stock and traction; III. Operation. There are 55 articles altogether, i.e. 13 in Part I, 33 in Part II and 9 in Part III.

These figures at once make it clear that the most diverse subjects have been covered. In fact they cover the whole technical field involved in the evolution of an important railway and its methods of operation.

As M. LEMAIRE says, the cornerstone of the ten year plan is the electrification programme. Consequently in Part II, electric traction is to the fore and is dealt with in 5 articles. In the first, M. DUGAS deals with the programme. In one of the others, the direct supply of single phase current at the standard industrial frequency to the locomotives is dealt with. This new method makes it possible to space the supply to the contact lines at very long intervals and opens up a new field of application to electric traction.

One of the leading ideas in the programme is the general increase in speed. The increased load on the rails and bridges is a result of this. Articles in Part I deal with the improved layout of the lines, the reinforcement of the lines on the main arteries, and the reconstruction of bridges. A note on the evolution of the steam engine in Part II shows that its power has increased by 40 % in twelve years and endeavours to define the field still open to the steam locomotive in view of its redoutable competitors. These whether electric locomotives or diesels or turbines are defined in their turn and their economic value and possibilities are clearly defined.

In the case of the passenger traffic, the quality of the services are to be improved not only as regards speed but also from the point of view of comfort, in spite of the weight reductions aimed at. This is brought out by the different notes on the new types of rolling stock.

In the case of goods traffic, the improvement in transport will result in the introduction of new regulations based on ideas of fast and ordinary traffic. In the collective note on the mechanism of dealing

with the traffic in both cases, the whole question of marshalling is gone into as well as the subject of stations and goods depots.

Safety occupies an important place. Under this heading, we can include notes on the braking of express trains, on the stability of vehicles, on the track, on the signalling. The telegraph system has profited by the latest discoveries in the electrical field.

As regards the working of points and signals, the latest progress has been the suppression of mechanical interlocking in the boxes with all the relays with route levers, and the studies made to extend these to the centralised traffic control installations.

As regards organisation, fruitful investigations have been completed covering the rational repair of locomotives, coaches and wagons.

Finally, as we have to draw the line somewhere, without failing to appreciate the value and interest of the other articles, we will mention the notes on the locomotive test plant at Vitry-sur-Seine, the trials of steam locomotives on the line, the central signalling laboratory, the S. N. C. F. isothermos laboratory, the mechanical tests of axle boxes and the analysing and test laboratories of the S. N. C. F., justified by the very diverse material in use, both as regards rolling stock and fixed equipment.

The illustrations, which are very abundant owing to the number and variety of subjects dealt with, have been very carefully selected and harmonise very well with the text. Plans of buildings, typical stations, locomotive sheds, photogravures of many types of rolling stock, drawings of modern tools, electric signalling diagrams, and maps of the lines to be electrified are all included.

Editions Science et Industrie with the collaboration of the most qualified specialists of the S. N. C. F. have produced a document showing the extent of the renovation undertaken in a very noteworthy form. It is a volume in every way worthy of those who have taken part in the work of perfecting the French railway system.

E. M.

[**721** .1]

REYNOLDS (Henry R.) Assoc. M. Inst. C. E. and PROTOPAPADAKIS (P.). Assoc. M. Inst. C. E. — **Practical problems in soil mechanics.** — One volume ($5 \frac{1}{2} \times 9$ in.) of 216 pages with 92 figures. — 1948, Crosby Lockwood & Son, Ltd., 39, Thurloe Street, London, S. W. 7. (Price : 18 s. net, cloth bound.)

The first studies concerning this subject go back to the year 1776, being those of Coulomb whose formulae are still in use at the present time. In their preface the authors recall the principal stages covered. These are marked by studies written by learned men and experimenters whose contributions have developed into a sufficiently coherent whole to merit the name of a new science.

The book is well planned to justify this consecration. Whilst making it possible to see how the different ideas are linked together, it covers all the kinds of work in connection with which the engineer has to study the soil with which he is dealing in order to analyse its behaviour.

The object of the book is not theoretical however. As the title explains, and a preliminary note makes clear, it is a question of formulating and solving the problems encountered in the application of the established formulae. The problems dealt with are those that a civil engineer is likely to encounter in fact. They have all be solved right down to the final detail,

to show whether the proposed construction will have sufficient stability or on the contrary the plans must be modified.

No special mathematical apparatus is required; the calculations are all elementary. There are merely a few diagrams of the static graphs, and the nomograms which the authors themselves have drawn up in order to facilitate using the formulae. These merely confirm the practical nature of the work.

The elementary ideas which form the basis of soil mechanics are given in the two preliminary chapters. They deal with the way in which a soil is analysed according to its composition and its physical properties, and then its ability to stand up to the stresses which will be caused when alterations are made or new loads placed upon it. This is completed by the methods and apparatus used for carrying out tests and measurements.

With the question of slopes we come to the real problem of stability. Treated first of all in a general way, this is then gone over again when dealing with cuttings and embankments. The interest is not confined merely to the problems and calculations involved. An examination of the methods of carrying out drainage and consolidation is also included. Three chapters are devoted to retaining walls, with the sheeting of large masses of earth and the strutting of the excavations.

In the case of the important question of the foundations for large buildings Boussinesq's formula is used to calculate the pressure at the different depths in terms of the horizontal distance of the load. These are developed to deal with settlements of the ground and the necessary calculations to ascertain the final value, the degree of uniformity and evolution to be expected. It may happen that research shows that the building should be modified.

When the composition of the soil lends itself thereto, it can be improved by the addition of coagulants. In other cases it is necessary to work with the protection of artificially coagulated masses or by keeping back the water level. The working technique and the conditions of application are analysed in a special chapter.

Another chapter deals with the stabilisation of the soil, and surface treatment which will prolong the life of roads and air fields.

Finally, as was inevitable, the authors have dealt with the prospecting of the terrain and taking soundings. The advice they give is very wise, together with many valuable data, and they discuss the circumstances which affect the number and siting of the borings taken, together with a description of the equipment used to take samples. Diagrams of the borings show how inadequate prospecting may lead to miscalculations, whilst further work would have led to adequate measures being decided upon.

A perusal of this book will enable even those who know very little about the subject to learn how to make use of the formulae and methods used, a knowledge of which is needed in this very essential field of engineering skill. A well chosen bibliography will be found most useful by those who wish to read the works of the most qualified writers on this subject.

E. M.

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